Iron AND Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

ECHNOLOGY DEPT:
010 EMPIRE BUILDING

May, 1943

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JUN 2 1943
PITTSBURGH, PA.

INTO THE LINE OF DUTY WITH BETTER ROLLED STEEL

Better finish - increased tonnage. Lewis Rolls and Rolling Mill Machinery combine to help speed up production.

LEWIS ROLLS

LEWIS FOUNDRY & MACHINE DIVISION OF BLAW-KNOX CO., PITTSBURGH, PA.

Answers to Many Pushbutton Control Problems

Cutler-Hammer's New Wide Range Line of Heavy Duty Pushbutton Stations offers an Unlimited Variety of Functional Combinations

● Now Cutler-Hammer offers a new line of Heavy Duty Pushbutton Stations (NEMA Type 1) for surface mounting and for flush mounting. The surface mounting enclosures accommodate from 1 to 8 Cutler-Hammer new unitized pushbuttons; the flush mounting constructions accommodate from 1 to 3 C-H unitized pushbuttons. The line provides the widest selection of functions and combinations available today and permits these stations to be "tailored" to your exact needs.

Among the many advanced engineering features are the following: one to 4 circuits for each pushbutton; wide variety of operators; big buttons for gloved-hand operation; projecting shatterproof color caps for 180° visibility; fitted "flange-seal" covers for extra sturdy and tight enclosure; rugged yet light weight construction; ample internal free space for easy wiring despite small size; no sharp corners or edges; excellent appearance; optional padlocking feature. Stations may be mounted horizontally or vertically. Write for further details today. CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee, Wis. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ont.

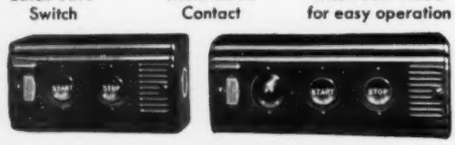
ARMY E NAVY
Milwaukee Plants.

SOME OF THE OUTSTANDING FEATURES OF THIS LINE

Wide choice of operating elements with one to 4 circuits each, indicating lights, selector switches, etc.

Plain Pushbutton — Indicating Light — Selector Switch

Latch-Safe Switch — Maintained Contact — Mushroom Head for easy operation



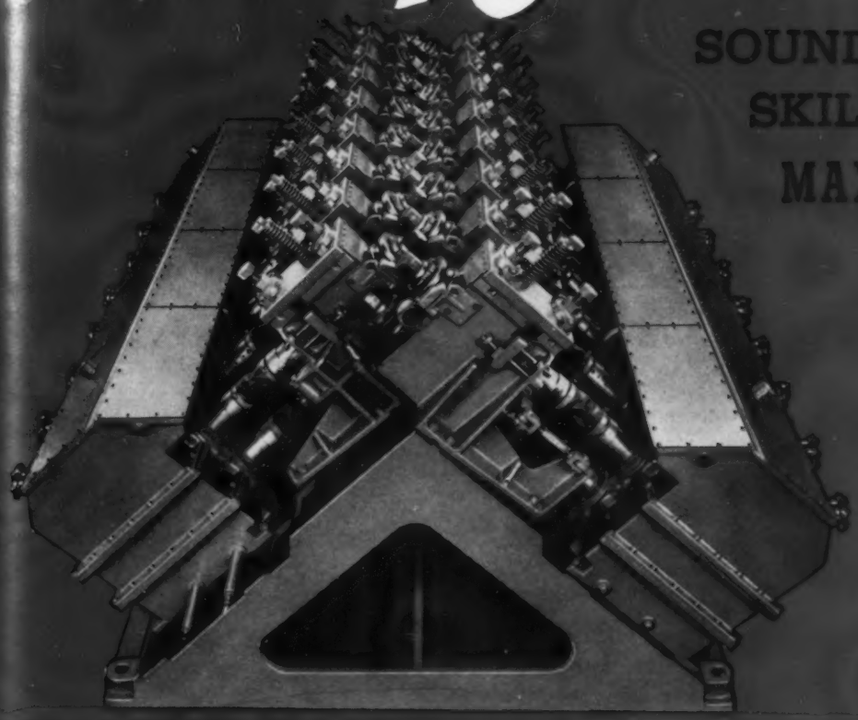
Horizontal as well as Vertical Mounting

Fitted Flange Seal Covers — Ample Wiring Space despite — Padlocking Arrangement Available

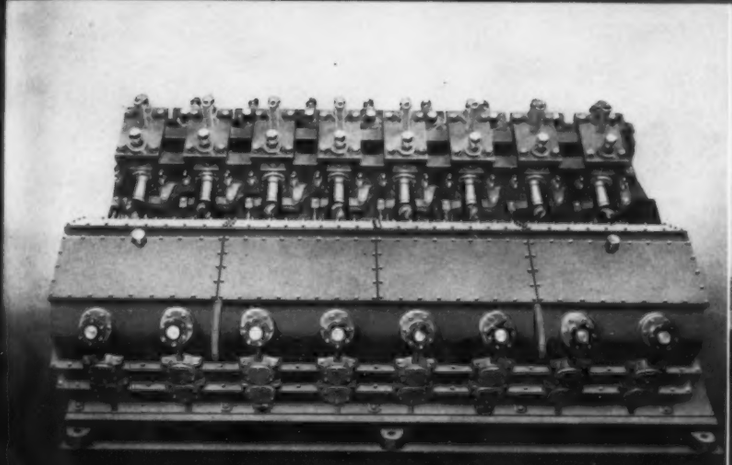
CUTLER-HAMMER
MOTOR CONTROL
C-H

THE AETNA 16 STAND REDUCING MILL

SOUNDLY ENGINEERED- SKILLFULLY BUILT FOR MAXIMUM PRODUCTION



Aetna Tube Reducing Mills are built in single or multiple stands with single or multi-motor drives. These mills are built to handle a wide range of tube sizes. At the left is a view of a sixteen stand individually driven mill for reducing tubes up to three and one-half inch diameter at two hundred to four hundred fifty feet per minute.



Above, left: Motors are omitted to show general view of drive housing and roll stands. Above, right: This view shows the staggered arrangement of the motors driving the mill.

ARMY E NAVY

DESIGNERS AND BUILDERS TO THE STEEL

The AETNA-STANDARD ENGINEERING COMPANY

★ YOUNGSTOWN, OHIO, U.S.A. ★

NON-FERROUS AND CHEMICAL INDUSTRIES

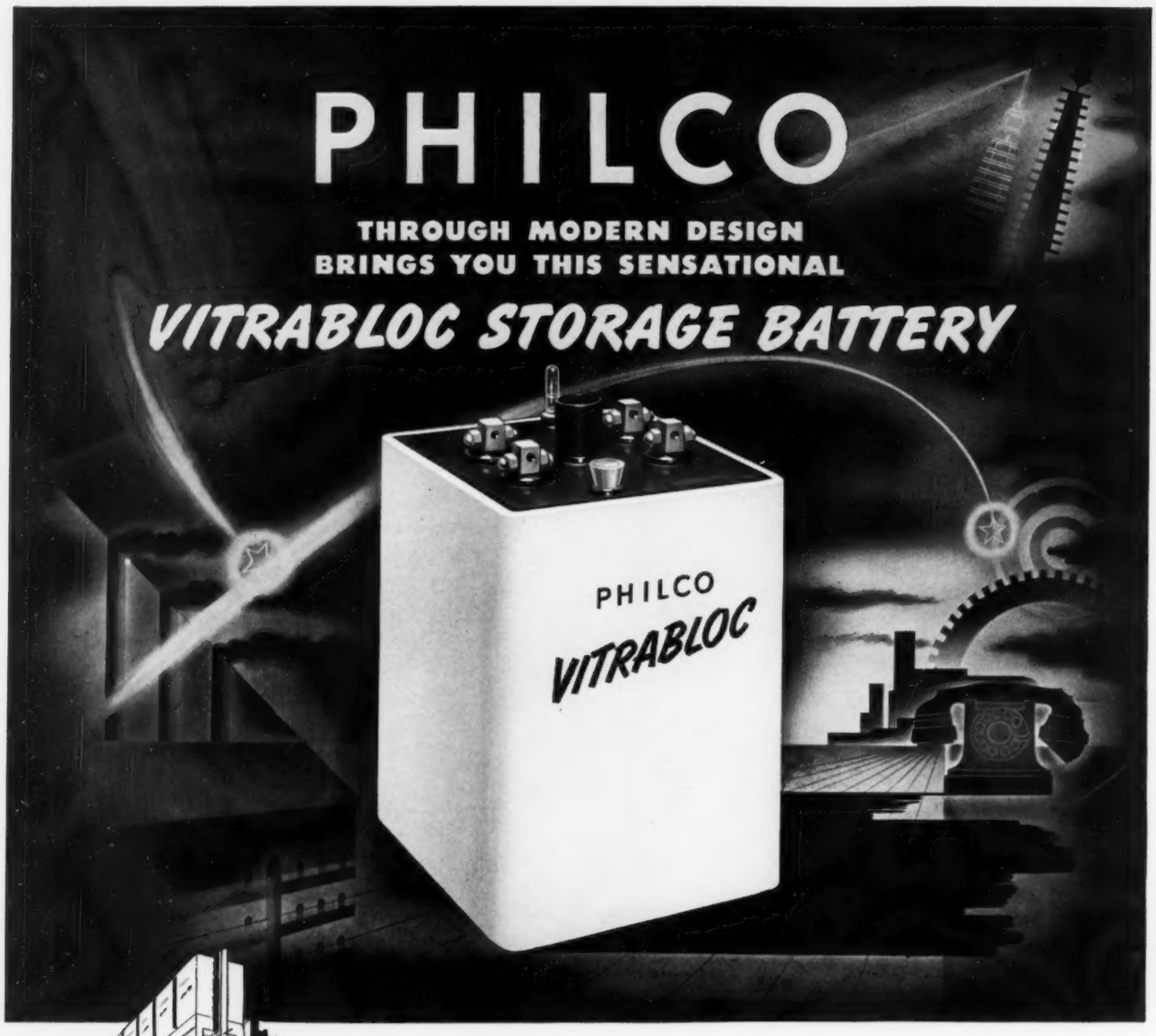
ASSOCIATED COMPANIES

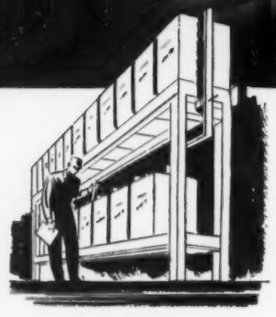
HEAD, WRIGHTSON & COMPANY, LIMITED, THORNABY-ON-TEES, ENGLAND • JOHN INGLIS COMPANY, LIMITED, TORONTO, ONTARIO, CANADA

PHILCO

THROUGH MODERN DESIGN
BRINGS YOU THIS SENSATIONAL

VITRABLOC STORAGE BATTERY





Philco Floté in Vitrabloc is the most attractive industrial storage battery ever made. Pure white, highly glazed, Vitrabloc brightens dark battery rooms.

FOR CONTROL, STAND-BY AND TELEPHONE SERVICE

Even in peacetime, Philco Vitrabloc would be a tremendous advance in storage battery construction. Today, when batteries must do a bigger job . . . when critical materials are a problem—Vitrabloc is a truly sensational development!

Philco Vitrabloc batteries give you greater capacity without increase in battery space. Vitrabloc incorporates the exclusive Philco Floté principle, the only construction specially designed for modern, full float service. Vitrabloc cells are explosion-proof and spray-proof.

Best of all, no critical materials are used in this vitrified ceramic jar! You can get Philco Vitrabloc batteries on exceptionally low priority!

For advanced engineering and construction in industrial batteries, specify Philco! Call your local Philco Battery representative . . . there's one in every important industrial center!

PHILCO CORPORATION, STORAGE BATTERY DIVISION, TRENTON, NEW JERSEY

REPLACE WITH RUGGED, HIGH-CAPACITY PHILCO BATTERIES

"Bridgeport" TRADE MARK

BRIDGEPORT BRASS COMPANY

BRIDGEPORT, CONN.

AKRON, OHIO
ATLANTA, GA.
BOSTON, MASS.
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CINCINNATI, OHIO
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SEATTLE, WASH.

Let THE INDUSTRY SPEAK OF OUR DESIGN

March 5, 1941

Hydropress, Inc.
570 Lexington Avenue
New York, N.Y.

Dear Sir:

We are pleased to state, that after more than a year's operation of the 2000 ton Loewy tube extrusion plant, which was built and installed by your company for us, that we are very much pleased with the entire outfit, and have no suggestions to make as to improvement of design.

The machine is exceptionally well built, the adjustments for alignment are adequate, the hydraulic valves are giving excellent satisfaction, the pump is the best we have in our plant, and the air-hydraulic accumulator system has been working with entire satisfaction.

Your company is to be congratulated on the complete adequacy of design, and the careful attention to workmanship which has been given in order to make this plant the success that it is.

Very truly yours,

WRClark
H

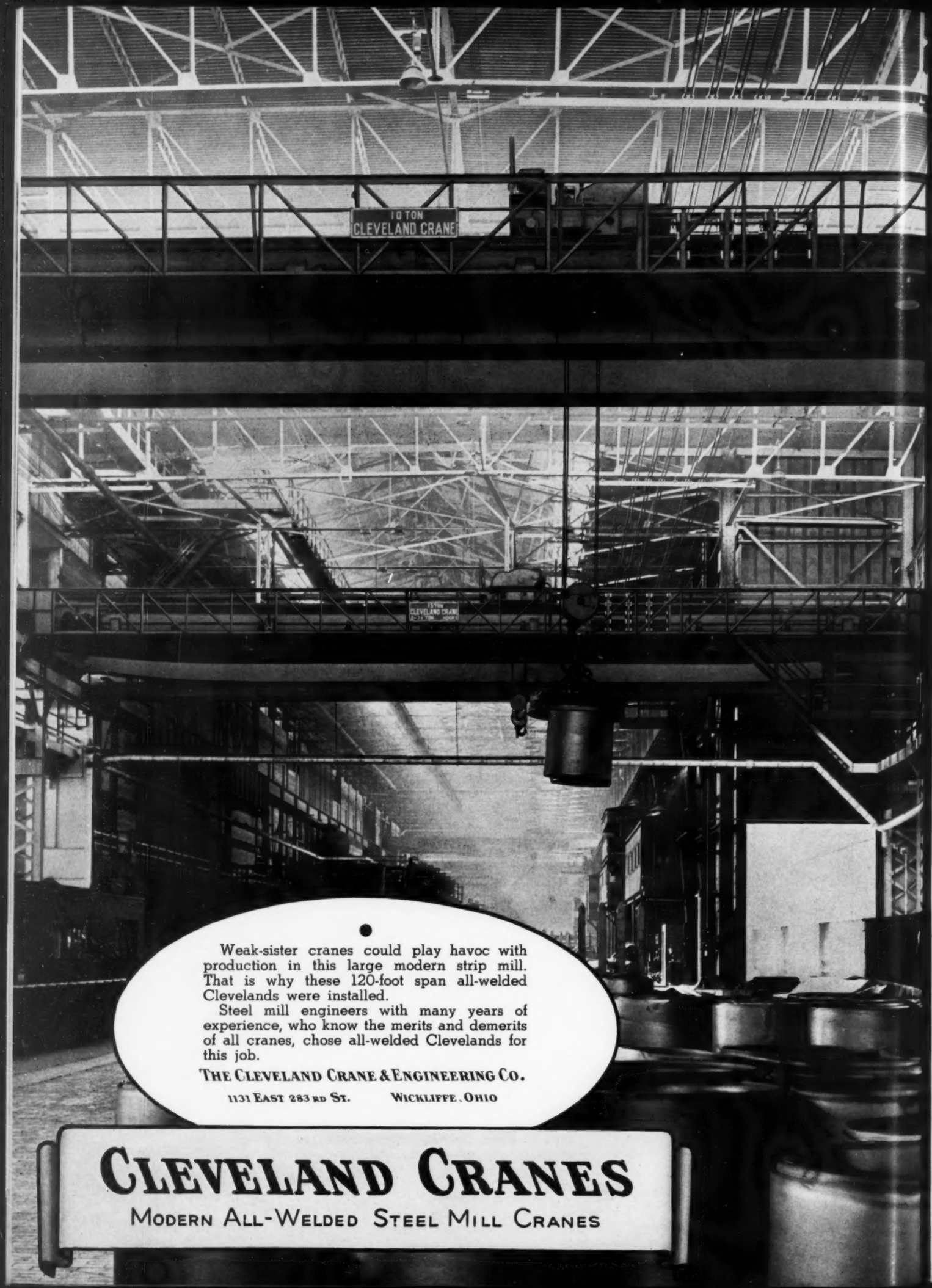
Works Manager
Mill Products Division

HYDROPRESS · INC.
ENGINEERS CONTRACTORS
HYDRAULIC PRESSES · ROLLING MILLS
PUMPS · ACCUMULATORS
570 LEXINGTON AVENUE · NEW YORK · N. Y.

UNITED
BLOOMING AND
SLABBING MILLS
ALL TYPES, ALL SIZES
INCLUDING
THE WORLD'S LARGEST

UNITED ENGINEERING *and* FOUNDRY COMPANY

Pittsburgh, Pennsylvania, U·S·A



Weak-sister cranes could play havoc with production in this large modern strip mill. That is why these 120-foot span all-welded Clevelands were installed.

Steel mill engineers with many years of experience, who know the merits and demerits of all cranes, chose all-welded Clevelands for this job.

THE CLEVELAND CRANE & ENGINEERING CO.

1131 EAST 283 RD ST. WICKLIFFE, OHIO

CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

Crops *and* Shorts

RECORDS continue to fall under the continued upsurge of production efforts throughout the steel industry. March, always a month of records, brought new highs in ingot production (7,670,187 net tons) and in pig iron production (5,247,792 net tons). Part of this is of course attributable to new expansions. However, it is even more encouraging to see existing units continue to set new records. Thus, 171,440 tons of ingots rolled on one blooming mill in the month, and a daily average of 1565 tons of iron from one blast furnace reflect the actual results of the efforts of the industry's engineers and operators — greater production from "know-how" rather than from new construction.

▲

THEY say, however, that there is no rest for a man who does everything his wife tells him to do. Lest the industry's very creditable showing in production and new records lull us into complacency, let us remember that 1943 production has been estimated at 92,000,000 net tons of ingots. This record tonnage will require speedy completion of some of the new blast furnaces now under construction, and of the new 14,000 ton ore carriers also under construction. And — not the least important — it will require 25,000,000 tons of outside scrap, which will not flow in through the transom, but will require continuous efforts.

▲

IF we are permitted to disagree without seeming disagreeable, we'd like to mention what a blessing it is that our industrial production hasn't followed the pattern which Congress seems to be using in setting up the income tax!

▲

REMEMBER when we were led to think the Japs comic little imitators, to be viewed with amused tolerance?

▲

SETTING a new attendance record of over 800, the annual meeting of the Open Hearth Committee and Blast Furnace and Raw Material Committee of AIME, held in Cleveland, April 29-30, presented a fine program devoted to sustaining the production of quality iron and steel to meet war requirements. Problems of personnel, materials, and processes were discussed. High spot of the meeting was the address of H. G. Batcheller, director of WPB's steel division. Mr. Batcheller stated that third quarter steel requests from various agencies totaled 21,000,000 tons of finished carbon steel, against 15,000,000 tons available for allocation. Hence, far from relaxing, we must have "production, more production, and still more production."

▲

AT the same meeting, some figures were presented on the place of women in the steel industry. It was felt that before the year's end, the use of women will approach the British level of 12-15 per cent. It was stated that the use of women in the United States has brought no drop in efficiency, but in some cases has resulted in a gain in efficiency, and a drop in absenteeism. Too bad we can't make miners out of them.

▲

A FREAK tornado at Cleveland recently destroyed the bracing holding up an ore bridge under construction, did not disturb the bridge itself.

▲

IT has been widely felt that the various technical and engineering organizations in the United States have not been used to best advantage in the country's war effort. Each organization has, in its own way, endeavored to do what it could, amounting in some cases to a substantial contribution. For example, the Association's book, "The Modern Strip Mill," was stated to have been of immense value to WPB in the conversion of strip mills to plate production. Another item showing specific results is the Association's crane specifications. One crane manufacturer reports worthwhile results in the form of a 30-40 per cent reduction in girder weight, saving 40-63 tons of steel in each crane. And so the record runs. However, much more could have been done had these organizations known definitely what the various government agencies needed — an item of information, incidentally, that direct inquiries usually failed to uncover. In spite of the need for direction of effort, however, it does not seem that the establishment of a new Federal office of scientific and technical mobilization, as advanced by the bill introduced before the United States Senate by Senator Kilgore, is the right answer. The closer the technical societies might be to the actual government agencies regulating production, the better the results that might be expected. Development and coordination of the facilities of the engineering groups might be effected much better by the various branches of WPB, and certainly, the job would not be a complicated one. It would take no more than a simple request to obtain the maximum facilities that each organization has available.

▲

CASUALTIES from industrial accidents in 1942 were 40 times greater than casualties in the United States armed forces, according to B. F. Fairless in a recent speech in Pittsburgh.

The WEAN

ENGINEERING COMPANY, Inc. • WARREN, OHIO

SPECIALISTS IN SHEET, TIN AND STRIP MILL EQUIPMENT

HEAVY PLATE LEVELLERS

HI-SPEED SHEET AND TIN MILL SHEAR LINES

ELECTROLYTIC & BONDERIZING TIN PLATE EQUIPMENT

WILSON TUBE ANNEALING FURNACES

WEAN VACUUM CUP SHEET AND PLATE LIFTERS

CONTINUOUS STRIP PICKLING, SLITTING, SIDE TRIMMING, AND RECOILING LINES

Associated Companies

LEE WILSON ENGINEERING CO.
CLEVELAND, OHIO

FLINN & DREFFEIN CO.
CHICAGO, ILL.

THE McKAY MACHINE CO.
YOUNGSTOWN, OHIO

THE HALLDEN MACHINE CO.
THOMASTON, CONN.

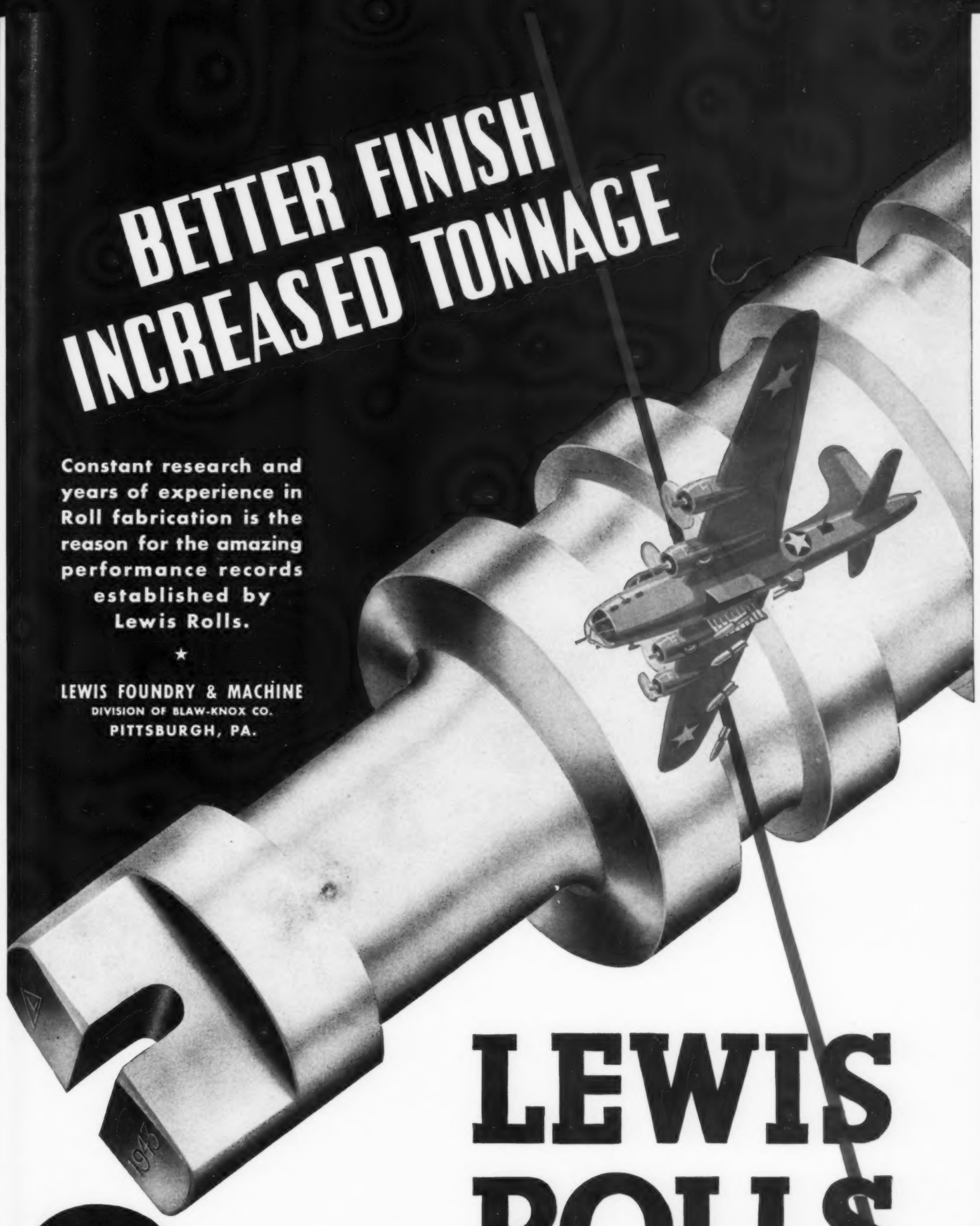
THE WELLMAN SMITH OWEN ENGR. CORP., LTD.
LONDON, ENGLAND

THE WEAN ENGINEERING CO. OF CANADA, LTD.
HAMILTON, ONT.

Subsidiary Company
THE BRODEN CONSTRUCTION CO.
CLEVELAND, OHIO

★ ★ SPECIAL MACHINERY for WAR PURPOSES ★ ★

BETTER FINISH INCREASED TONNAGE



Constant research and years of experience in Roll fabrication is the reason for the amazing performance records established by Lewis Rolls.

★

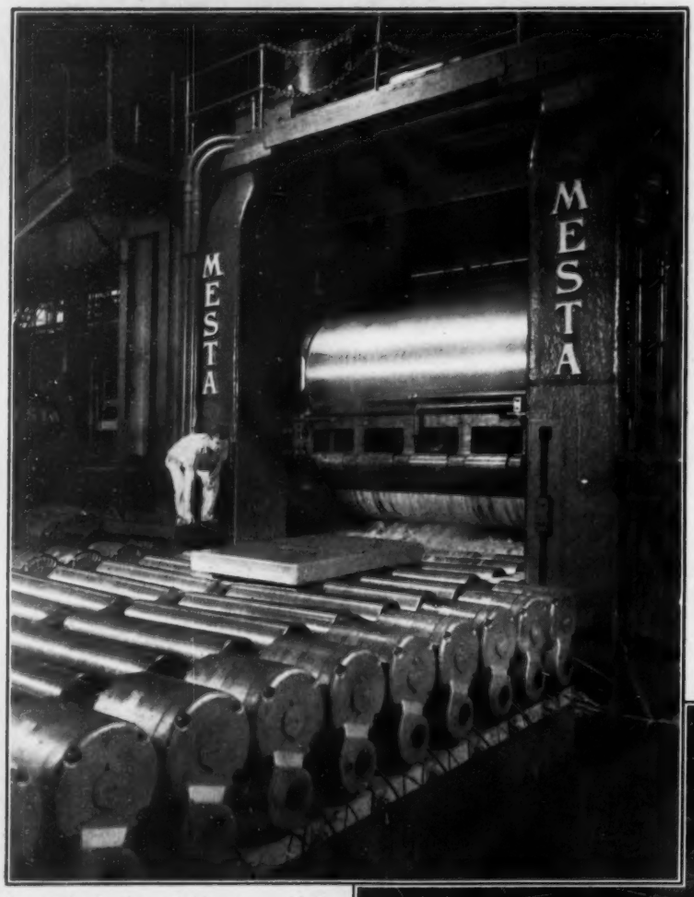
LEWIS FOUNDRY & MACHINE
DIVISION OF BLAW-KNOX CO.
PITTSBURGH, PA.

LEWIS ROLLS

Also manufacturers of
ROLLING MILL MACHINERY
for the iron, steel and non-ferrous industries

★ ★ ★ ★ FOR VICTORY BUY U. S. WAR BONDS AND STAMPS ★ ★ ★ ★

MESTA FOUR HIGH MILLS



Partially Reduced Aluminum Slab
at Roughing Mill

for... *Rolling* ALUMINUM and other NON-FERROUS METALS

The First Four-High Tandem Mill Installed in This Country
For the Production of Wide Aluminum Strip Sheets

The Army-Navy "E" Flag
with two stars, flies
over the Mesta plant.

MESTA MACHINE COMPANY . . PITTSBURGH, PA.

ROLLS AND STEEL MILL EQUIPMENT
HEAVY DUTY MACHINE TOOLS
CASTINGS · FORGINGS

A new generation of industrial workers is learning about Exide dependability!

New workers are enlisting every day in America's industrial battle. Many of them have been unfamiliar with motive power batteries and the equipment powered by dependable Exides . . . but that picture is changing fast. The simplicity, efficiency, and long life of Exide Ironclad Batteries is convincing these new workers of something experienced operators have always known . . .

Exide IRONCLAD BATTERIES

. . . are leading a war of movement on the home front!

ANY WORKER CAN FOLLOW THESE EASY MAINTENANCE STEPS . . .

Keep adding approved water at regular intervals. Most local water is safe. Ask us if yours is safe.

Keep the top of the battery and battery container clean and dry at all times. This will assure maximum protection of the inner parts.

Keep the battery fully charged—but avoid excessive over-charge. A storage battery will last longer when charged at its proper voltage.

Record water additions, voltage, and gravity readings. Don't trust your memory. Write down a complete record of your battery's life history. Compare readings.

If you wish more detailed information, or have a special battery problem, don't hesitate to write to Exide. We want you to get the long life built into every Exide Battery. Ask for booklet form 1982.

Exide IRONCLAD BATTERIES

1 **High Power, More Production:** To get the most from any battery-powered electric vehicle, its battery must deliver good voltage, hold that voltage high, and be ready for emergency demands with a giant surge when needed. Exide Ironclads do just that.

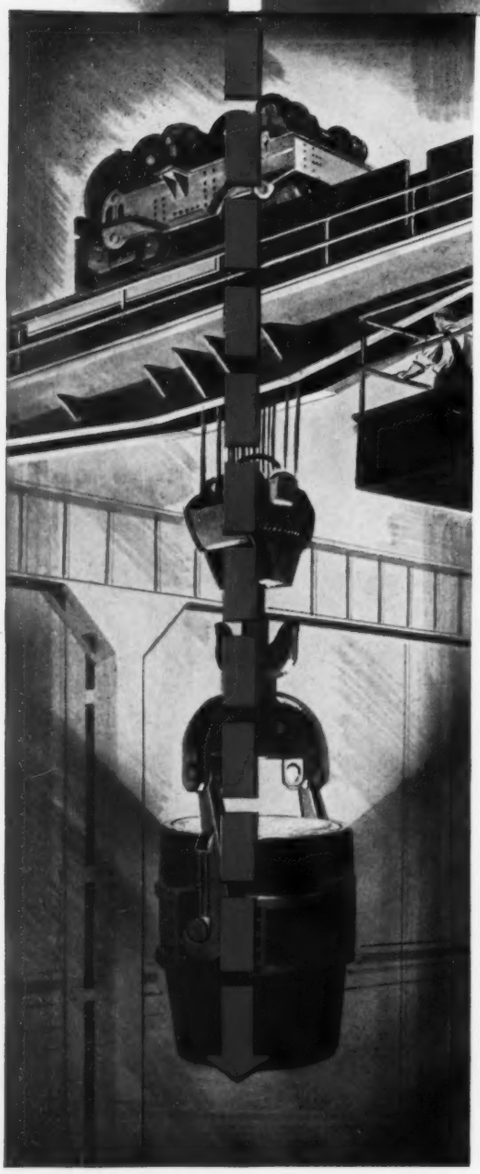
2 **Long Life, Saves Materials:** Rugged Exide Ironclads are built to last, and save vital materials by getting maximum use from everything that goes into their making. When you buy an Exide you definitely —Buy to Last and Save to Win!

3 **Easy Maintenance Saves Labor:** Exides are kept charged by the simplest method ever devised. With the Exide Charge Control Unit there's nothing to do but connect the battery to the charging source and turn a knob.

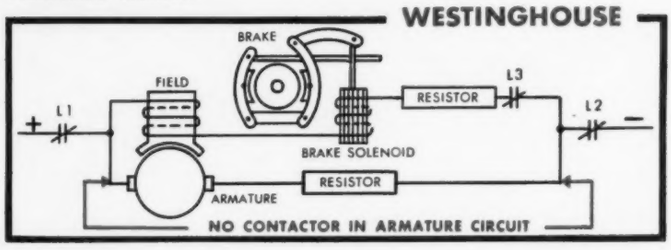
THE ELECTRIC STORAGE BATTERY COMPANY, Philadelphia
Exide Batteries of Canada, Limited, Toronto

SAFE! ALL the way down

with Westinghouse Safety Circuit for D-C Crane Control...



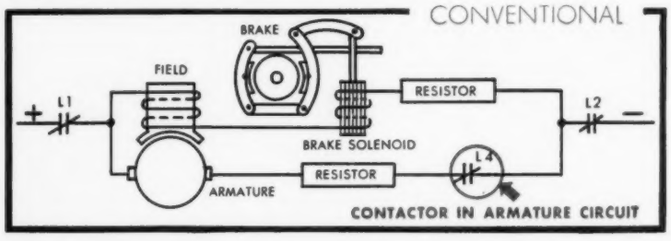
This Westinghouse patented safety circuit makes crane lowering safety completely independent of any possible contactor failure.



Westinghouse achieves this safety by eliminating all contactors in the armature circuit, thus keeping the armature solidly connected across the main line contactors at all times. When the solenoid brake is released, dynamic braking action automatically takes over.

HERE'S HOW:

When lowering, gravity tends to spin the armature. By reversing the field in the Westinghouse safety circuit, the armature stays solidly connected across the line contactors. The motor then acts as a loaded generator and a retarding dynamic braking action takes place. Should the line contactors (L_1, L_2), or field reversing contactor (L_3) fail, the solenoid brake will set. Consequently, lowering safety is completely independent of possible contactor failure.



In conventional circuits, the armature is reversed instead of the field, making contactor (L_4) necessary in the armature circuit. Should this contactor fail while the solenoid brake has been released for lowering, the open circuited armature will be free to spin. Since no braking action of any sort will then be available, the load may drop.

Specify Westinghouse "Safety Circuit Control" for your crane—or call your nearest Westinghouse office for complete crane control information. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa. J-21260

Westinghouse MOTORS & CONTROL

PLANTS IN 25 CITIES... OFFICES EVERYWHERE

ONE OF A SERIES OF SUGGESTIONS TO AID PRODUCTION

HOW TO SOLVE

Operating Problems with *Correct Lubrication*

A "Cushion" for Impact Loads

PROBLEM: There's a lot of oil going over those gears above, yet when it gets between the gear teeth shock loads will squeeze it to microscopic thinness. The result is boundary lubrication. That means a special oil is needed to prevent film rupture and resulting excessive wear of the gear teeth.

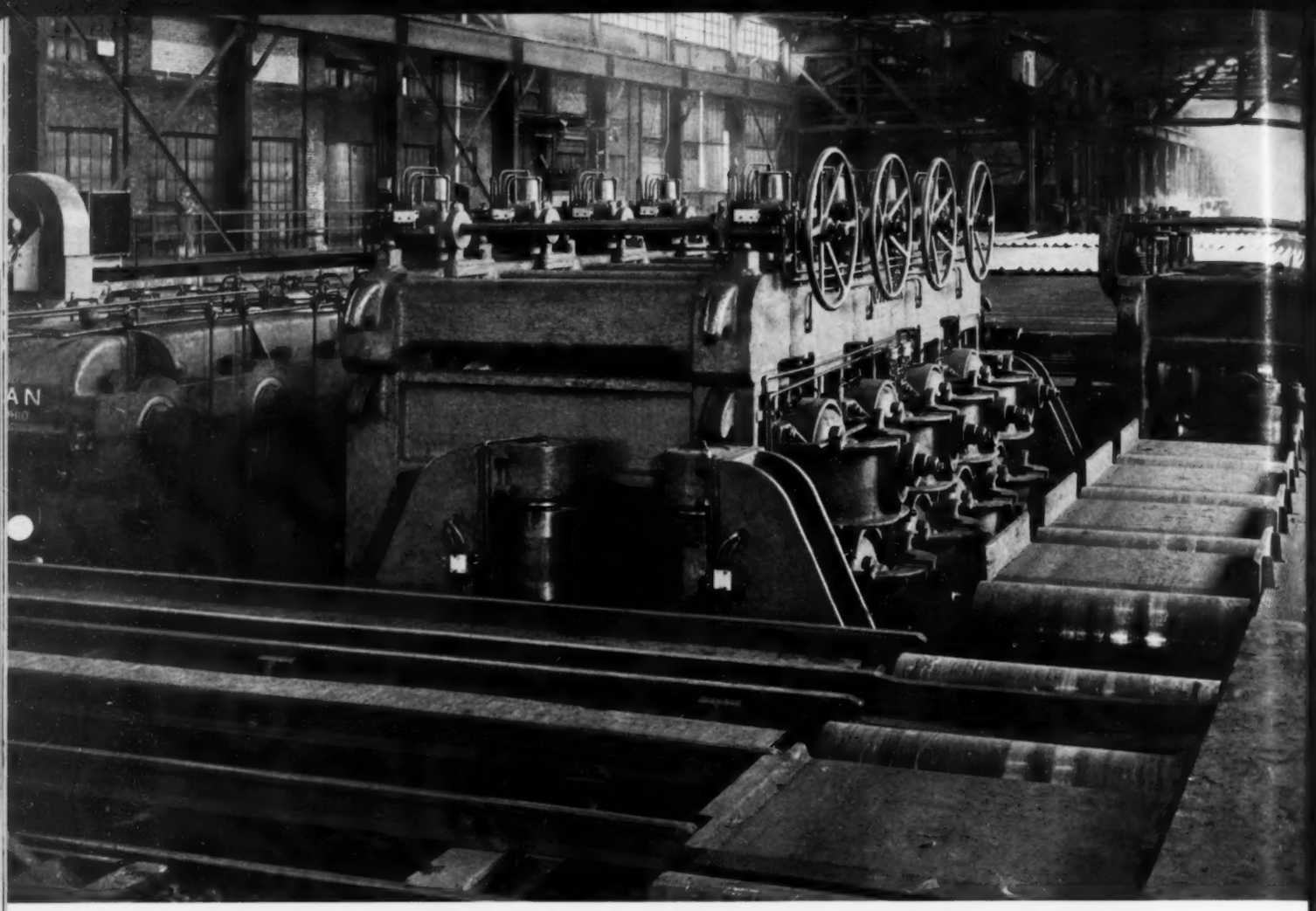
ANSWER: *Gargoyle Compounds* were developed to lubricate circulation and bath-oiled high-duty gears. Their tenacious film bonds with the metal to resist the rubbing and squeezing action of extremely heavy loads. As a result friction and wear are minimized.

NOTE: With this lubricant no special products are needed for "run in."

GARGOYLE Lubricants

SOCONY-VACUUM OIL COMPANY, INC. — Standard Oil of N. Y. Div. • White Star Div. • Lubrite Div. • Chicago Div. White Eagle Div. • Wadhams Div. • Magnolia Petroleum Company • General Petroleum Corporation of California

CALL IN SOCONY-VACUUM



24″ I BEAM STRAIGHTENER

● Illustrated is a Morgan Roller Straightener for structural shapes up to 24″ I beams.

It is equipped with four top and four bottom rolls, all of which are adjustable. These eight rolls are arranged to be connected by spindles to a separate enclosed gear box drive. All gear shafts are mounted in roller bearings. Vertical rolls are provided on both entry and delivery sides.

A section of roller table is mounted on one side of straightener to be shifted into the roller table line when straightener is not in use.

BUILT BY MORGAN *Engineering*

THE MORGAN ENGINEERING CO.
ALLIANCE, OHIO
Pittsburgh, 1420 Oliver Building

DESIGNERS • MANUFACTURERS • CONTRACTORS • BLOOMING MILLS • PLATE MILLS STRUCTURAL MILLS • ELECTRIC TRAVELING CRANES • CHARGING MACHINES • INGOT STRIPPING MACHINES • SOAKING PIT CRANES • ELECTRIC WELDED FABRICATION • LADLE CRANES • STEAM HAMMERS • STEAM HYDRAULIC FORGING PRESSES • SPECIAL MACHINERY FOR STEEL MILLS

Throw Your Scrap Into the Fight

HERE'S HELP!

In Training Crane Operators

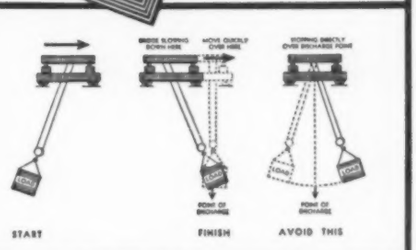
TELLS HOW
and
SHOWS HOW
to operate
efficiently

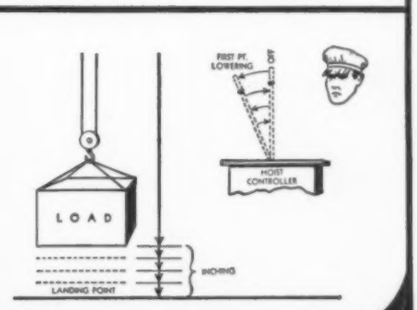
The first Crane MANUAL ON OPERATION ever published

Your copy is free! A simply written, easily understood 48-page Manual. 70 illustrations—two colors—handy, pocket size.

Contents include safety rules—operating hints—inspection-guide for daily report on condition of crane, suggestions on how to avoid trouble, etc. Explains and pictures what *not* to do as well as how to get *more* production safely.

Applies to direct current overhead cranes—*all makes*. Useful in training new operators—including women—also beneficial for the more seasoned operator. Send for your copy to-day. Ask for Booklet 920—"How to Operate a Crane."





Typical illustrations from the MANUAL

THE ELECTRIC CONTROLLER & MFG. CO.
CLEVELAND ★ **OHIO**

Today's Pioneers Are Planning Committees

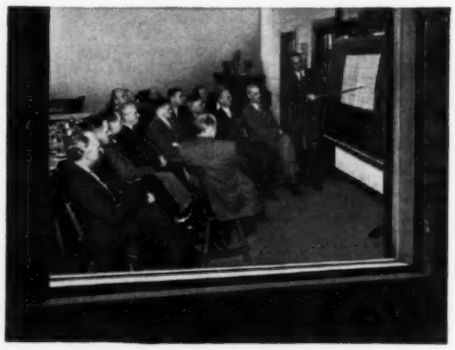
Out of the pioneer meetings came our early progress; out of today's Planning Committees in many organizations and industries will come security and prosperity for a new America.

Every Friday night at 1088 Ivanhoe Road the lights burn late while the Reliance Future Planning Committee is at work. At other times, these Reliance engineers, production and sales men devote their energy to making more war goods, quicker.

But, one night a week in true pioneer spirit, they tackle the problems of electric motors and motor-drive of the future. They start from scratch. They take nothing for granted. They assume there is a better way to build every motor; and that no motor-drive problem is unsolvable.

Their past performance is a guarantee of big things to come. They've licked some pretty tough assignments in many different industries—and even tougher ones for our armed forces. They have "on tap" many important developments in simple, flexible, production-boosting, electric motor-drive and control.

Reliance engineers—pioneers in their field—are available to help *you* with your motor-drive problems.



Friday Night at Reliance

RELIANCE A·C D·C MOTORS

RELIANCE ELECTRIC & ENGINEERING CO.

1088 Ivanhoe Road • Cleveland, Ohio

Birmingham • Boston • Buffalo • Chicago • Cincinnati • Detroit • Greenville (S.C.) • Los Angeles • New York Philadelphia • Pittsburgh • Portland (Ore.) • St. Louis • San Francisco (Calif.) • Syracuse (N.Y.) and other principal cities.

THE SHORT CIRCUIT...

That Moves Mountains

ON our far-flung fighting fronts, and along our industrial front, a short circuit *in harness* is increasing the deadliness of our war weapons, speeding war production, conserving vital man power and materials. Its name—the G-E AMPLIDYNE.

In principle, the amplidyne is an externally driven d-c dynamo-electric machine. By unique use of a short circuit, together with load-current compensation, General Electric engineers have combined in it such high amplification and speed of response that tiny electrical signals release *kilowatts* of output capable of controlling the heaviest machinery.

With strength and amazing speed, the amplidyne executes the whispered orders of relays, selsyns, limit switches, electronic tubes, resistances—almost any source of control current. It maintains continuous control of voltage, current, speed, or position, instantly correcting any departure from the desired conditions.

The thousands of G-E amplidynes now in industrial and war service point to a future that challenges the imagination. The amplidyne will simplify your electrical systems and make them more flexible. Because its characteristics are permanently built-in, it will assure consistent performance year after year, yet it can be readily adjusted to meet changing requirements. It has a place wherever an electrical signal can express the need for a change, or prevent a change, in process.

To help you fit this versatile new tool into your plans for present and post-war improvements in product or process, G-E application engineers offer their full co-operation. Call on them freely.

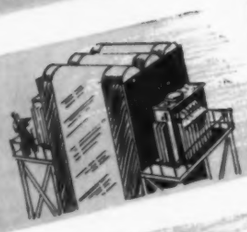
GENERAL ELECTRIC

OUTPUT STEPPED UP

150 tons per shift—on giant cold-strip mills

DEADLINESS INCREASED

—of our land, sea, and air weapons



REJECTIONS DROPPED 50%

—on two tin-plate flow-brightening lines

CAPACITY ROSE

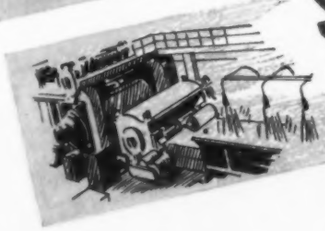
70,000 tons per month—on the world's largest shovel

SPEEDS CLIMBED

—in the performance of high-speed planers

VARIETY WIDENED

in the number of grades of paper that could be made on a single machine



SAVINGS TOTALLED $30,000

—in the cost of a new flying-shear installation

AMPLIDYNE

WHAT THE AMPLIDYNE DOES

CONTROLS SPEED

—accurately—over a wide range. Matches machine speeds to maintain continuous process control.

SPEEDS UP ACCELERATION

and deceleration, to increase production of high-inertia machines.

LIMITS LOADS

—to protect electric systems, to eliminate shock loads and destructive stresses on mechanical equipment.

POSITIONS PRECISELY

for fast and accurate setting of machine tools, arc-furnace electrodes and other equipment.

HOLDS TENSION

—to improve product uniformity in winding, rolling, and drawing operations.

REGULATES CURRENT,

voltage, power, and speed to maintain steady conditions, to improve power factor.

General Electric Company, Sec. 750-203
Schenectady, N. Y.

Yes, please send me your booklet "The Short Circuit That Moves Mountains".

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Company.....

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Mail the coupon today for your free copy of "The Short Circuit That Moves Mountains", 28 pages with photographs and circuit diagrams showing what the G-E AMPLIDYNE does, how this unique amplifying generator operates, and where it can help you.

GENERAL ELECTRIC

1893 **50th** 1943

ANNIVERSARY

On reaching a fiftieth anniversary, whether it marks an individual's life, the length of a marriage, or the span of a corporation's existence, it seems appropriate to hesitate for a moment to reflect on past memories as well as prospects for the future.

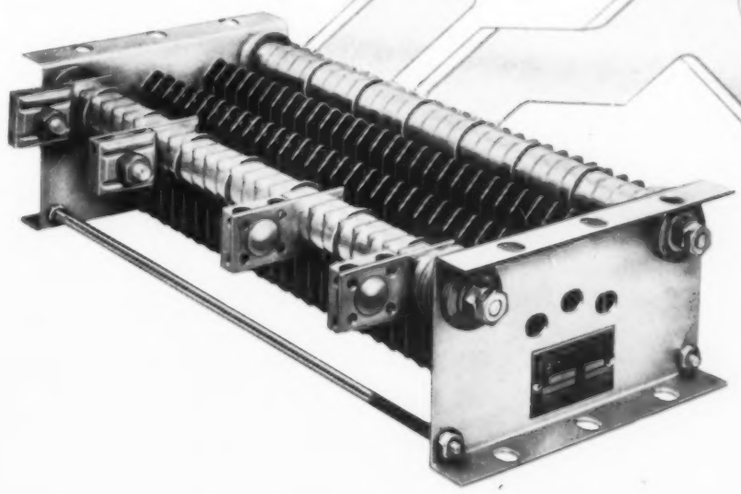
The Post-Glover Electric Company is fortunate to have lived thru fifty years which have brought electrical industry from infancy to maturity. As successor to a previous partnership, corporate life began May 3rd, 1893. Since that date, first as a distributor, and later as a manufacturer, a diversity of electrical equipment and supplies has been furnished to industry.

More than twenty-five years ago, Post-Glover introduced the steel grid resistor, a forerunner of the "non-breakable" steel grid resistor now favored for heavy duty applications, particularly for production of metals, minerals, and for transportation service.

With the development and improvement of P-G Steel Grid Resistors, other activities have gradually been curtailed with practically all production now confined to resistors. This concentration of purpose and evolution to one main product is largely responsible for the reputation for dependability and prompt service of which The Post-Glover Electric Company is rightfully proud.

Today, prompt service is becoming more difficult to maintain but dependability of product remains constant as always. For the future, whatever that may hold, Post-Glover gives its pledge to continue the high standards of the past, and to provide the best service that war conditions will permit.

It has been a real pleasure — and of course profitable to serve you. Thanks Industry for your confidence, we shall try always to be worthy of it.



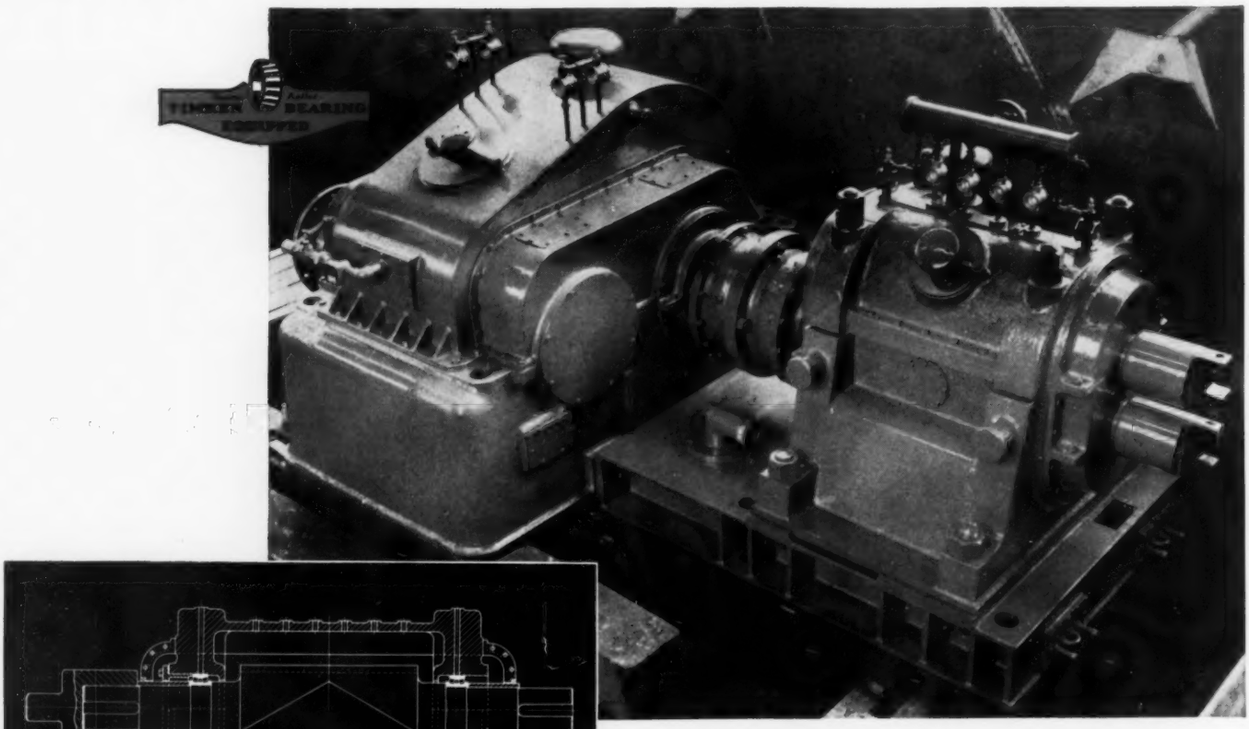
P-G

THE POST-GLOVER ELECTRIC COMPANY

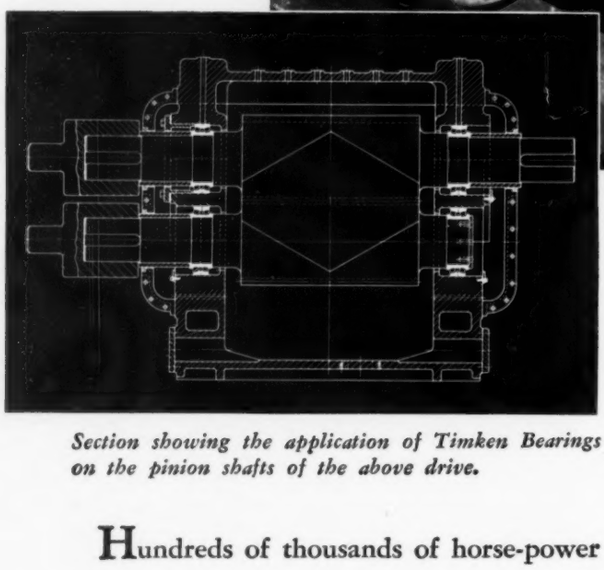
• ESTABLISHED 1892 •

221 WEST THIRD STREET, CINCINNATI, OHIO

DRIVING TO VICTORY ON TIMKEN BEARINGS



United 800 H.P. rolling mill gear drive and pinion stand equipped with Timken Bearings.



Section showing the application of Timken Bearings on the pinion shafts of the above drive.

Hundreds of thousands of horse-power are required to keep America's metal rolling mills operating at Victory production speed. Most of this power is transmitted through Timken Bearing Equipped gear drives and pinion stands.

A considerable saving of power results from mounting gear drive and pinion stand shafts on Timken Tapered Roller Bearings; there is no friction to burn it up. Furthermore, shafts and gears are held in constant alignment; radial, thrust and combined loads are safely carried; lubrication is simple and positive; maintenance is greatly reduced and the life of the equipment extended.

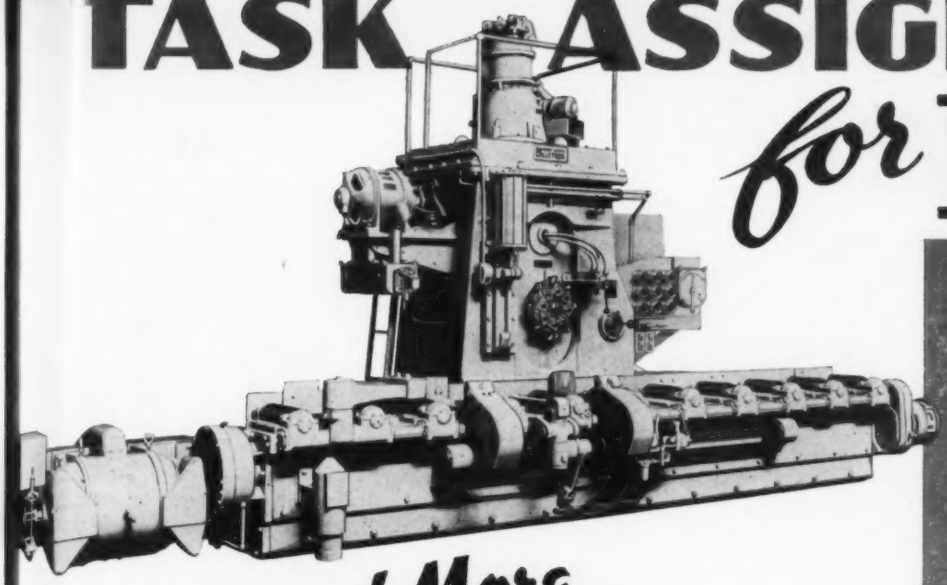
With Timken Bearings in the drives and on mill back-up and work roll necks, top-notch operation is assured — not only as regards volume of output, but also the quality of the product; for Timken Roll Neck Bearings assure *precision* as well as speed and endurance. The Timken Roller Bearing Company, Canton, Ohio.

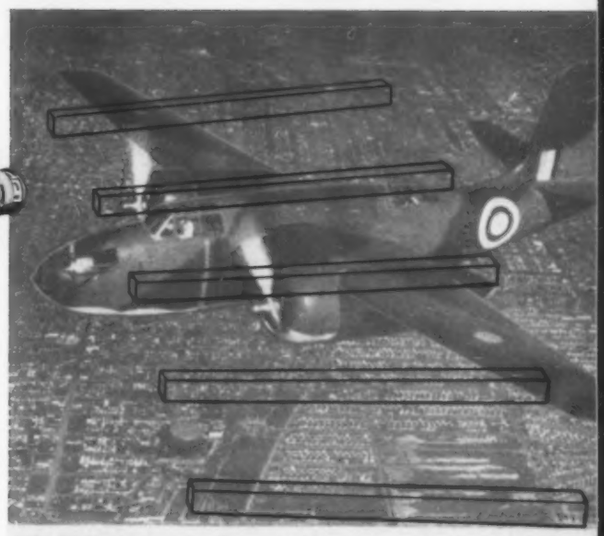
"All There Is **TIMKEN** *In Bearings"*

TRADE-MARK REG. U. S. PAT. OFF.

TAPERED ROLLER BEARINGS

TASK ASSIGNMENT *for* 1943





More and More Better and Better Faster and Faster

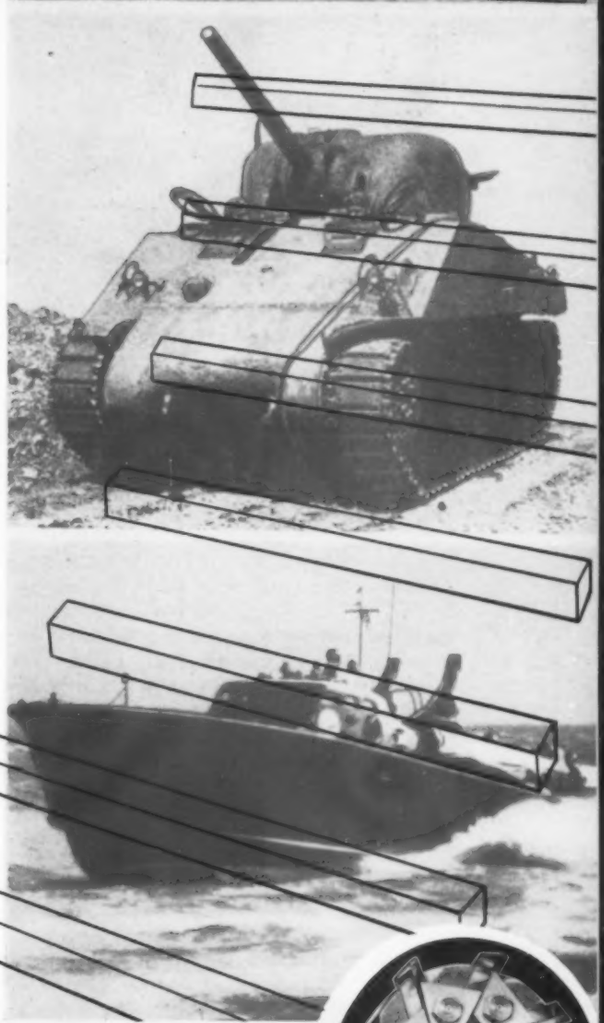
BILLET CHIPPING.

To beat the axis, we must outstrip them in the production of *materiel* — and the surest way is to *modernize* every department that acts as a brake on steel delivery schedules.

Every piece of fighting equipment made of metal is formed from billets, and one of the most glaring examples subject to production improvement is in billet cleaning departments where the work is done by hand.

The answer is MECHANIZED billet chipping, and the means is a BILLETEER, with its proved record of cleaning heavy tonnages of billets *10 to 20 times faster* than by hand chipping. The tougher the steel and worse the defects, the greater the saving over other methods — in time, electric power, man power, and billets. The BILLETEER, under the finger-tip control of ONE operator, is uncanny in the speed, ease, flexibility, and instant responsiveness of its operation.

Don't let slow, costly methods of billet cleaning retard your delivery schedules — get the facts on the BILLETEER — write us today.

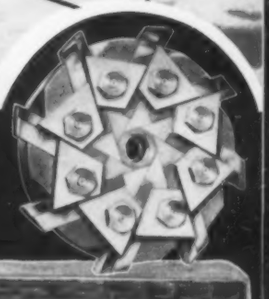


THE **Bonnot** COMPANY
STEEL EQUIPMENT DIVISION
CANTON, OHIO

TIMKEN BEARING EQUIPPED

BONNOT-LENTZ

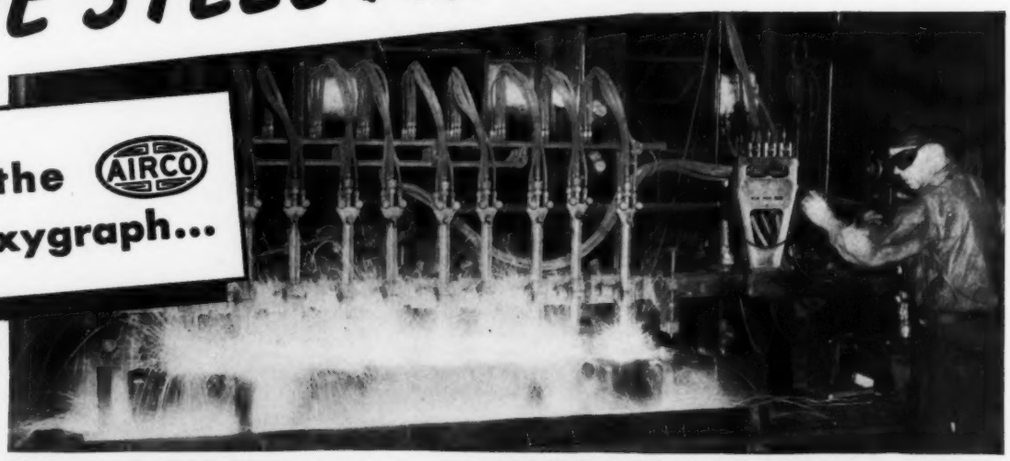
BILLETEER



A MECHANIZED SUPER PRODUCTION BILLET CHIPPER

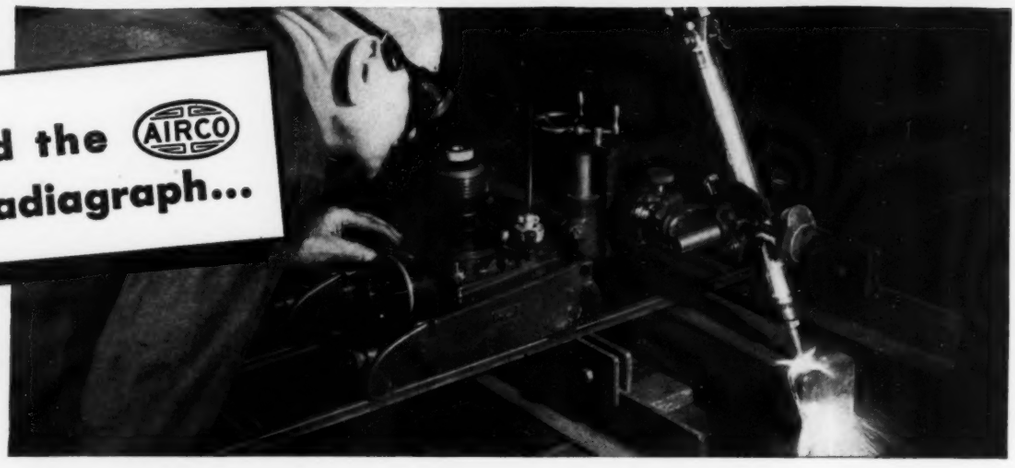
SHAPE STEEL FAST...

...with the AIRCO No. 6A Oxygraph...



No. 6A Oxygraph with ten torches, cutting seamless tubular headers at the rate of 100 per day for Combustion Engineering Co.

...and the AIRCO No. 4 Radiagraph...



An Airco No. 4 Radiagraph making a bevel cut in a steel bar, only one of many jobs within the range of this portable machine.

Reasonably prompt deliveries on relatively high priority ratings

These two Airco gas cutting machines are now available in limited quantities for essential work carrying relatively high preference ratings. Both machines have gained wide acceptance in metal working industries because of their precision, speed and wide range of uses.

The No. 6A Oxygraph is a stationary type gas cutting machine used for quantity production of metal parts. With a number of torches mounted on the machine, identical metal parts can be produced in quantity in a single cutting operation. Straight lines, bevels, or irregular shapes are cut from almost any commercial metal thickness quickly and accurately. A template of the required shape and size guides the movement of the mutliple cutting flames.

The Airco No. 4 Radiagraph is a remarkably versatile light weight (74 lbs. net), portable gas cutting machine which is widely used in steel mills, shipyards and other metal-working industries. It is motor driven and moves on a track placed upon the work. Straight line cuts, using one or two torches; beveled cuts with as many as three torches; circles and large radius curves are a few typical jobs performed by the Airco No. 4 Radiagraph.

For full information, prices, and delivery dates on both of these Airco machines get in touch with your nearest Air Reduction office.

Air Reduction

General Offices: 60 EAST 42nd ST., NEW YORK, N. Y.

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OFFICES IN ALL PRINCIPAL CITIES

AIRCO WILSON

IDLE CYLINDERS ARE PRODUCTION SLACKERS: *Keep 'em rolling for victory!*

10 12
Set at any desired control point
THROTTLING RANGE % OF REC. SCALE
RATE OF DROOP CORRECTION
Turn to any desired throttling range
Set any rate of automatic droop correction
Manual Control Knob
Switch
Throw switch for either automatic or manual control. Move knob to position valve manually. Knob indicates valve position.

Micromax is easily tuned to the furnace's needs — all settings are made at the front of the panel.

TO DEFEAT TEMPERATURE SWINGS
Make MICROMAX The Operator's Helper

Every setting and resetting of its temperature controller which any standard type fuel-fired furnace or oven could require is supplied with the Micromax Control equipment shown above.

We do not even have to know how much load-swing you anticipate, or how much lag; many users do send us such facts, but the Controller is completely adjustable to any such problem . . . the limits of satisfactory control, if there are limits, being determined by factors outside the Pyrometer.

Just tell us, when you specify Micromax, the make, size and type of valve; the fuel and air pressures; the type of thermocouple if you have preference; the range of temperature to be controlled; the amount of wire needed between couple, Micromax and valve; and whether you want to have the equipment mounted on panel as shown. The resulting installation will help you secure control of unsurpassed sensitivity, accuracy and dependability.

If a Catalog will answer your needs, ask for N-00A, Micromax Electric Control; our new, compact, fully-illustrated 30-page description of this equipment.

LEEDS & NORTHRUP COMPANY, 4942 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

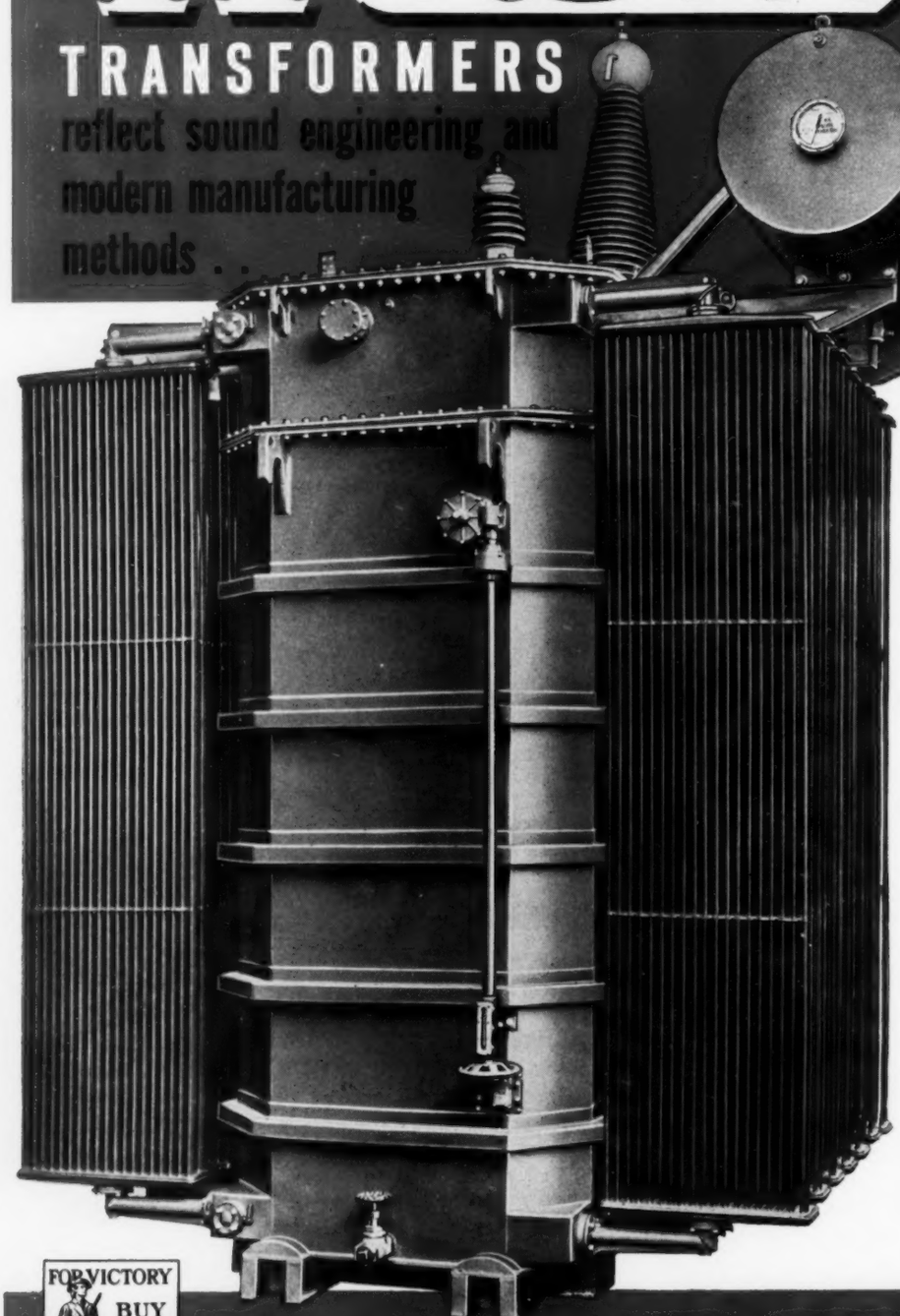
Jrl Ad N-33A(19)

In time of war and in time of peace . . .

Wagner

TRANSFORMERS

reflect sound engineering and modern manufacturing methods . .



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AIR-COOLED
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NOFLAMOL
(NON-INFLAMMABLE LIQUID FILLED)

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T43-3

Wagner Electric Corporation
ESTABLISHED 1891
6400 Plymouth Avenue, St. Louis, Mo., U. S. A.
ELECTRICAL AND AUTOMOTIVE PRODUCTS

3 OF A KIND—BUT DIFFERENT!

¶It takes three kinds of Engineers — all different — to produce "3C" Engineered Electrical Control.

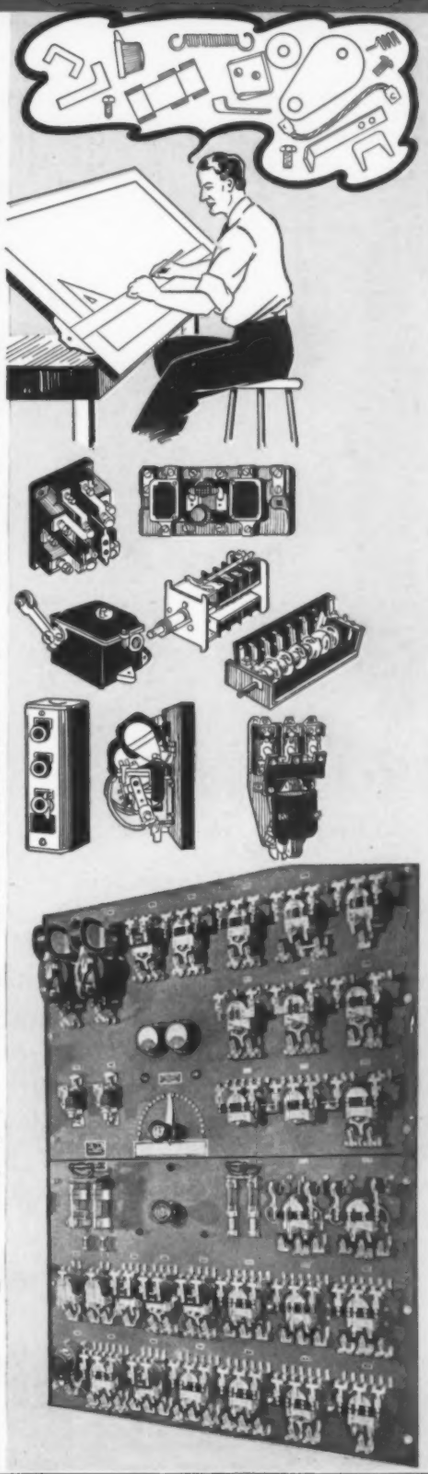
¶First, the Development Engineer. His problem is developing a definite piece of apparatus to do a definite job. Maybe he works out an entirely new principle of operation; or improves upon a standard design. Many of his ideas are not commercially feasible, but eventually he develops devices mechanically and electrically right, of simple construction, occupying minimum space, with wearing parts and terminals easily accessible, and plenty of wiring space.

¶Second, the Application Engineer. To him come the problems of recommending the right control for multi-motored machines, for continuous processing lines in mills, or for any of thousands of applications of electrical energy to modern industry. He knows what every piece of "3C" control apparatus will do under given conditions; he understands how to control and protect every type of electric motor; he studies the conditions such as moisture, heat, dust, fumes, gas, corrosion, and the duty cycle under which the control must function, and selects the "3C" apparatus best fitted to provide economical and reliable service to the user.

¶Third, the Design Engineer. His job is designing the finished panel. From the designated "3C" apparatus needed to control and protect a multi-motored operation, he arranges the various devices in a compact, efficient, workable layout, to provide simple effective wiring, with all parts easily accessible for maintenance. Perhaps the space for control is limited, and he has to use great ingenuity in arrangement of devices to fit the completed panel into the space. From his drawings actual construction starts. Panels are drilled; special devices are made, standard apparatus taken from stock; all parts assembled and wired. His careful work is reflected in low production costs, and in efficient operation of the entire panel assembly for the customer.

¶Of course there are dozens of other engineers—testing materials and apparatus, checking wiring and operation, doing many odd jobs all tending to produce efficient, trouble proof, low maintenance "3C" control apparatus.

¶They all work together to produce "3C" Engineered Control — engineered to fit your problems, and to operate efficiently under the conditions in your plant. "3C" Engineered Control is carefully planned, designed and built for the best economical, reliable operation, for we have all three types of Engineers.



CLARK ENGINEERED MOTOR CONTROL

is just another way of saying

"CORRECTLY ENGINEERED MOTOR CONTROL"

—a "3C" service available to you

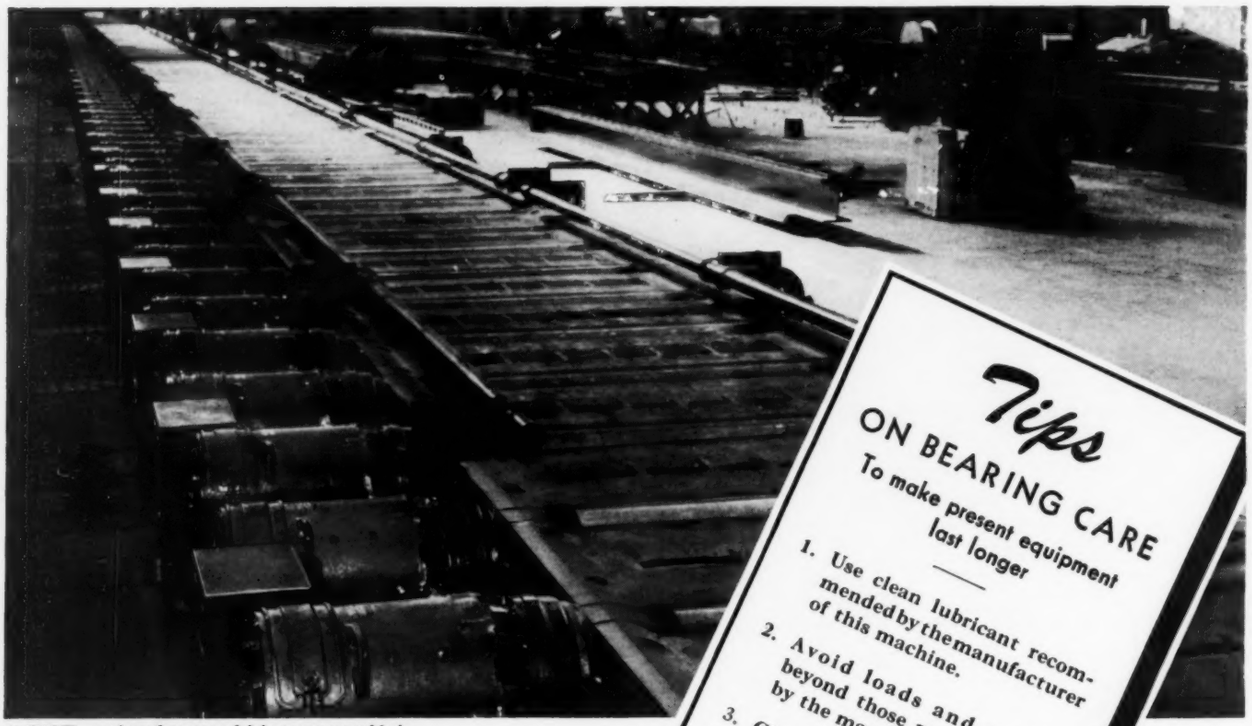
CONTINUE TO ROLL WITH CLARK CONTROL

THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO

Hot Strip Mills

ARE LICKING THE AXIS



● SKF-equipped motors driving runout table in 54" hot strip mill of The Youngstown Sheet & Tube Co.

Tips ON BEARING CARE

To make present equipment last longer

1. Use clean lubricant recommended by the manufacturer of this machine.
2. Avoid loads and speeds beyond those recommended by the manufacturer.
3. Check wiring and insulation frequently. Short circuits or stray currents can damage bearings.
4. If necessary to remove bearings, keep them properly lubricated. Avoid the intrusion of water and dirt. Apply pressure on the inner race only. Don't hammer outer race.

North and South—America's preponderance of hot strip mills are punching the Axis with st ɔped-up production from SKF-equipped machinery. One of the most modern is this Youngstown Sheet & Tube Company's 54-inch hot strip mill where SKF-equipped motors drive runout table rollers that speed "hot rolled" to its destination. Where tonnage is the thing that counts, SKF's help move steel at topmost speeds.

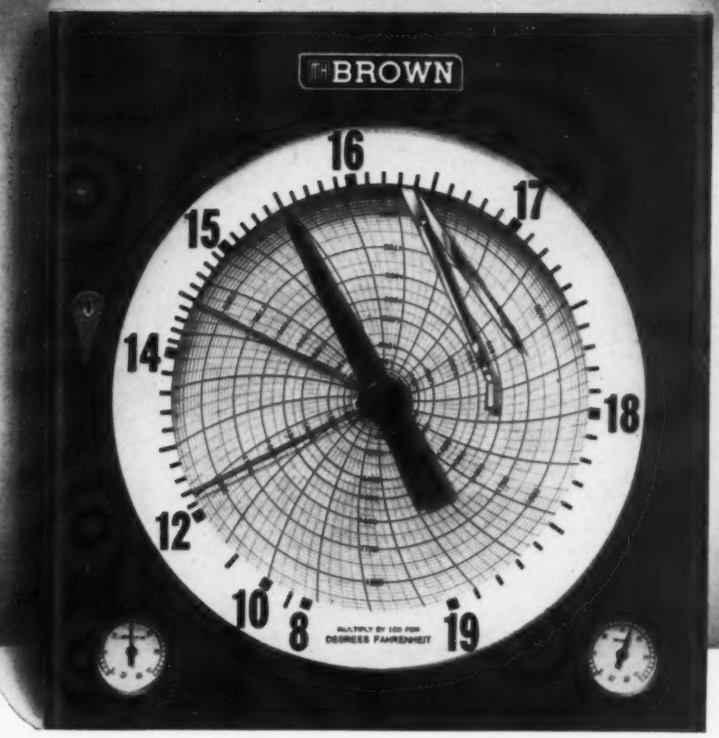
5295

SKF
BALL AND ROLLER BEARINGS

ARMY E NAVY

SKF INDUSTRIES, INC., PHILA., PA.

The Instrument of Tomorrow



WORKING *Today* IN THE WAR INDUSTRIES

THE Brown "*Continuous Balance*" *Air-o-Line* Potentiometer Controller is the culmination of more than three-quarters of a century of experience in building industrial measurement and control instruments.

The experience of the past combined with the demands of today have resulted in a new potentiometer air-operated controller that will meet the needs of many future years.

In this radically new potentiometer controller a "*Continuous Balance*" Unit takes the place of the galvanometer used in the conventional mechanical-type potentiometer employing a periodic or cyclic mechanism.

It is the only potentiometer-type instrument in which the air control flapper mechanism is *instantly* positioned in response to temperature changes.

The "*Continuous Balance*" measuring system makes it possible to take full advantage of thermocouple responsiveness. Positive control action is assured by the well-known, dependable Brown *Air-o-Line* Control Unit, thousands of which are in service throughout industry.

The Brown Circular Chart *Air-o-Line* Potentiometer Controller brings to industry, for the first time, the ideal synchronization of measurement and control for temperature processes.

BULLETIN SENT ON REQUEST

Outstanding features such as: Control Unit — Throttling Range Dial — Automatic Reset Dial — Booster Pilot Valve — Control Index Knob — Direct and Reverse Action — Compression Type Fittings — Control by-Pass Panel — Balancing Motor — Slide Wire — Pen Arm Release — Chassis — are fully described in Bulletin 15-4. Write for it.

BROWN

"Continuous Balance"

POTENTIOMETER CONTROLLER

THE BROWN INSTRUMENT COMPANY, 4464 WAYNE AVENUE, PHILADELPHIA, PENNSYLVANIA
DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPAN
MINNEAPOLIS, MINNESOTA AND 119 PETER STREET, TORONTO, CANADA
Wadsworth Road, Perivale, Middlesex, England — Nybrokajen 7, Stockholm, Sw

Every War Bond Tightens the Noose!

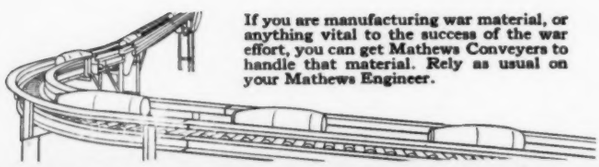
American money and machinery are slowly but surely weaving the noose which will strangle the war effort of enemy nations. Every Bond purchased hastens the day of reckoning for Hitler and Hirohito, and all the brutality and murder they represent.

The men and women in the Conveyer Industry are behind this strangling program in two vital ways —

First, by participating in War Bond buying plans which help our Government to finance the purchase of war material, to train fighting men, and to keep our national economy on as even a keel as possible —

Second, by an all-out production program to speed the engineering and manufacturing of conveying equipment for the faster production and movement of the implements of war.

The cost of the war increases each day. So must the purchase of Bonds increase day after day, until our enemies are beaten completely and finally.



If you are manufacturing war material, or anything vital to the success of the war effort, you can get Mathews Conveyers to handle that material. Rely as usual on your Mathews Engineer.

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Pittsburgh, Pennsylvania

IRON AND STEEL ENGINEER

MAY • 1943
VOL. XX NO. V

In This Issue

Some Metallurgical Aspects of Blast Furnace Operation — C. D. Smith, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania 33

Additives in Petroleum Products — By F. F. Musgrave, Assistant Director of Research, The Lubri-Zol Corporation, Cleveland, Ohio 40

Discussion: Additives in Petroleum Products — Presented by G. E. Reiser, J. B. Tuttle, S. C. Griffith, W. H. Mandy, F. F. Musgrave and C. E. S. Eddie 44

Blast Furnace Charging Equipment — By L. R. Milburn, Electrical Engineer, Great Lakes Steel Corporation, Ecorse, Michigan 47

Bearing Surfaces — By E. L. Hemingway, International Machine Tool Corporation, Elkhart, Indiana 53

Discussion: Bearing Surfaces — Presented by H. H. Wood, H. H. Shakely, C. C. Pecu, E. L. Hemingway, Charles Pritchard and C. R. Hand 58

Relation of Flame Character to Open Hearth Operation — By A. J. Fisher, Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland 61

Discussion: Relation of Flame Character to Open Hearth Operation — Presented by C. R. Taylor, A. J. Fisher, R. I. Gumaer, M. J. Bradley, P. F. Kinyoun, F. E. Leahy, E. E. Callinan, R. A. Lambert and W. C. Buell, Jr. 74

Immersion Heating — Determination of Flue Temperatures — By H. C. McRae, Research Engineer, The North American Manufacturing Company, Cleveland, Ohio 77

Latest Design and Equipment for the Industry 88

Items of Interest 98

Index to Advertisers 119

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2. Normal operating position.

MOORE RAPID

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Top charge Lectromelt furnaces are speeding up steel melting through fast charging which reduces the time between heats. Illustrated is a 10 ton capacity "OT" Lectromelt top charge furnace. Lectromelts of the top charge type are available in sizes from 100 tons to 250 pounds.

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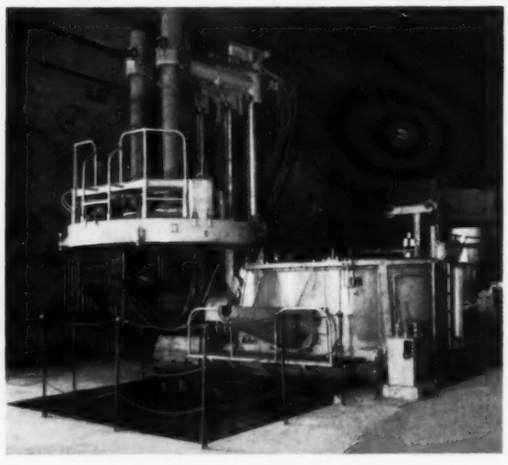
PITTSBURGH LECTROMELT FURNACE CORPORATION

Pittsburgh .... Penna.



3 Roof raised and rotated ready for charging.

SOME *Metallurgical Aspects* OF *Blast Furnace* OPERATION

..... this statistical study of blast furnace data shows iron production to be improved by coal washing, by control of operating temperature and scrap additions, by use of the best raw materials, and by the lowest practical molar basicity .....

by C. D. Smith

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▲ METALLURGICAL study of blast furnace operations has not received the same attention as other branches of the steel making industry, although a mass of data has been available from charts, burden sheets, and other operating reports. Realizing that a careful analysis of these data might provide leads for the betterment of iron production and quality, a metallurgical statistical study was initiated at the Pittsburgh Works of Jones & Laughlin Steel Corporation. The immensity of the problem the blast furnace operator faces is realized only too well. Most of the trends shown in this paper are already well recognized by the operator, but it is hoped that their quantitative effect can be used for a more direct control from both an iron quality and production standpoint.

While it has always been the aim to produce maximum iron tonnage from blast furnace units, war conditions make this an acute necessity. Much stress has been placed on iron production throughout the country and several new blast furnaces have been built, with others still under construction. This increased iron tonnage is being utilized in the open hearth shops through the medium of high iron and ore charges. This practice serves a three-fold purpose in that it helps relieve the scrap shortage, reduces iron ore directly to steel in the open hearth furnace, and permits faster open hearth production rates. Where bessemer converters are available, any excess iron tonnage can also be used in duplexing or making bessemer ingots.

Three solid raw materials, iron ore, coke, and limestone charged in at the top of the blast furnace, meet the air forced in at the tuyeres near the bottom, result-in two currents moving in opposite directions; a slow current of solids descending, and a rapid current of gases ascending. While the furnace operator cannot control these currents completely, he is usually able to maintain a balance by controlling the wind, blast temperature, and amount of materials entering the furnace.

Inspectors were placed at the furnaces in September 1941 to cover the operations and record data for further study. The object of this coverage is to develop means of more positive blast furnace control, determine the effect of various factors on blast furnace operations, and to assist the blast furnace personnel. Our work to date has covered No. 4, No. 5, and No. 6 furnaces at the Pittsburgh Works, during the period September 1, 1941 to March 1, 1942 on No. 4, and since June 1, 1942 on No. 5 and No. 6 furnaces. All furnaces were producing bessemer iron.

The making of iron in the blast furnace involves a smelting of iron ore, usually about 50 to 55 per cent Fe, with sufficient fluxing materials to remove the gangue. Much depends on the type of ore used and how it conforms in analysis with respect to silicon and phosphorus. As these elements fluctuate so must the methods of operations be regulated to meet the changing conditions. The physical size of the ore should be kept within reasonable limits in order that a satisfactory distri

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ution of stock is maintained within the furnace. The importance of good distribution of the burden within the furnace has been repeatedly shown whenever it has been necessary to operate for a short time without the use of the small bell. Coke ash and sulphur content together with strength and bulk density are also important. The first control points, therefore, should be instituted at the ore mines and by-product plant.

One of the most important factors influencing iron production and iron analysis is temperature. Iron temperatures are taken on each cast by the blast furnace inspector using an optical pyrometer. The effect of iron temperature is well known; generally a cold furnace produces iron low in silicon and high in sulphur, while a hot furnace produces iron with a high silicon and low sulphur content. Neither iron is a good product to send to the bessemer or open hearth departments. At the bessemer, a low silicon iron might result in cold blown bessemer steel which will mean a loss in yield due to poor pouring and heavy skulls, with further losses at the chipping beds in the form of larger scrap losses and higher reconditioning costs. Scrap which is normally added as a coolant must be omitted since the temperature of the blown metal is not adequate using low silicon iron. During normal times, this method of utilizing scrap is most desirable since it is the quickest and most economical means of converting scrap to ingots. A high silicon iron causes formations in the convertor called kidneys and excessive slopping of iron from the mouth of the vessel. When these kidneys become large, an excessive number of blanks have to be placed in the convertor bottom which increases blowing time, thus reducing production. Slopping causes an increased number of "off analysis" and generally poorer quality blows due to the varying amount of metal lost. High silicon iron is objectionable to the open hearth also since it deoxidizes the bath, causing an increase in furnace time, increases the amount of fluxes necessary and attacks the furnace bottom. A low silicon iron is desirable for open hearth metal, but care must be taken to keep the sulphur within certain limits. Several companies are following a desiliconizing process which keeps the silcon content at the point which the open hearth people desire.

Figure 1 is a correlation showing the effect of iron temperature on the production rate of No. 4 furnace. Those casts on which the wind blown was under 52,000 cubic feet per minute were excluded. This condition was due to mechanical difficulties with the blowing engines. As shown, the highest rate of production was obtained with an iron temperature range of 2690 to 2750 F. Within the range of temperature observed the decreased production amounts to about 17.1 per cent at temperatures lower than 2660 F., and 10.7 per cent for temperatures higher than 2810 F. Only about 35 per cent of the casts observed were within the temperature range for optimum production indicating the possibility of closer temperature control improving production on 65 per cent of the casts. Assuming that the optimum temperature range were in effect, a calculation indicates that 5 per cent more iron would have been produced over the casts studied.

Since there is an iron specification to meet, which in this case is 1.10 to 1.60 silicon with .050 maximum sulphur (bessemer iron), the rate of production cannot be studied without consideration of the chemical analysis of the iron being made. Figure 2 shows the characteristic silicon-sulphur relationship with respect to iron temperature. It is interesting to note that the temperature at which optimum production is obtained shows an average silicon range of 1.15 to 1.40 and average sulphur range of .035 to .055. While the sulphur obtained with this temperature range is rather high, statistical study indicates that the cost of reconditioning

Figure 1 — Effect of iron temperature on iron production.

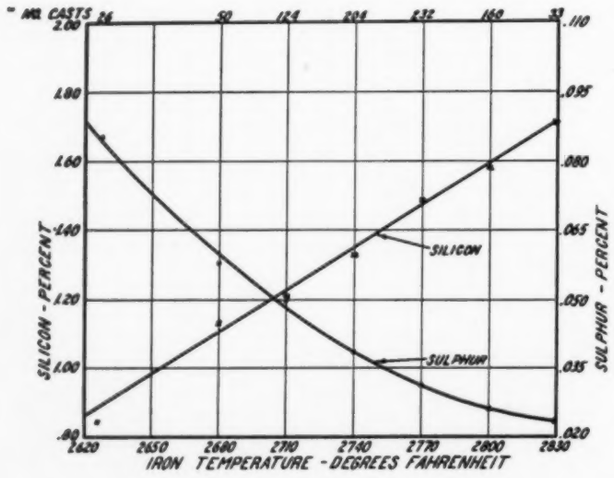
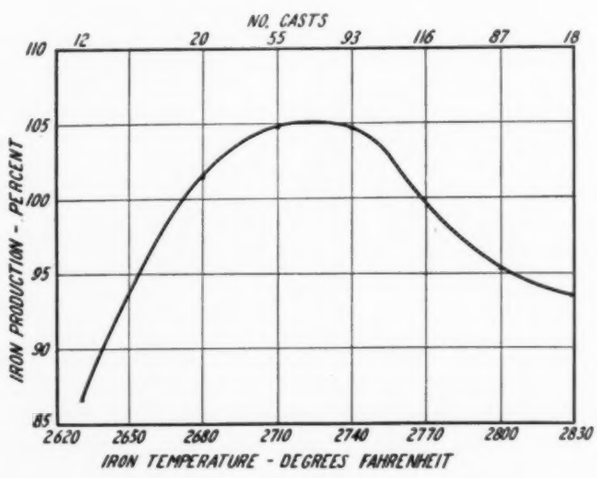


Figure 2 — Relationship between iron composition and temperature of bessemer iron.



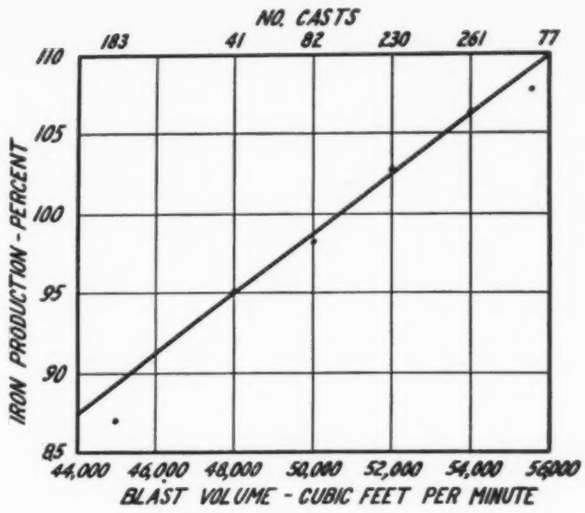


Figure 3 — Relationship between blast volume and iron production.

bessemer screw steel, which is the principal grade made, would not be increased. The effect of iron sulphur on machinability, within the range studied, indicated a slight increase in machinability as the sulphur in the iron increased. Even with the low sulphur bessemer steels we understand that some bessemer operators add sulphur to low sulphur iron in order to increase the sulphur to about .035 to .045 for the best bessemer ingots. All the above tends to confirm the idea that no particular penalty is suffered if the sulphur in the iron runs up to .050 maximum. However, when making low sulphur bessemer steel for the strip mill this element must be kept under .030. The blast furnace people are notified when these grades are to be made and the furnaces are burdened to give this sulphur limit. There is also the possibility of running a lean burden on the furnace to increase production, then desulphurizing with soda ash or some such desulphurizing agent. Iron desulphurization is being investigated by quite a few companies and we would expect further progress in this direction with the present need for additional iron production.

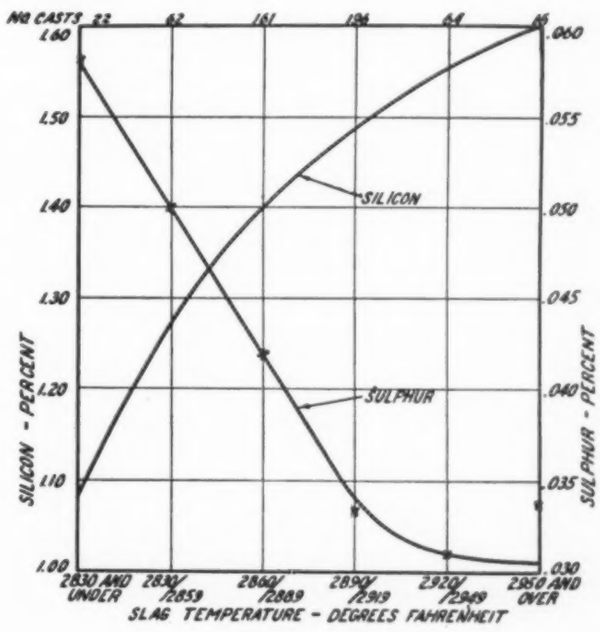
When it appears that the furnace is getting a bit cold, there are several ways by which it may be righted. Sometimes a slight increase in blast temperature will suffice; a more positive effect may be obtained by a "cut" in ore burden; and a still more positive effect by charging blanks of coke. The quantity of blast can also be reduced although this practice is avoided unless absolutely necessary. In each of these cases, with the possible exception of the change in blast temperature, the tons of iron made will be reduced. Our present ore burden practice is to charge as much ore as the furnace will take. If the furnace is hot, additional ore is charged until at last the furnace "cools off".

While the effect of the blast volume on iron production is generally known, it is interesting to review the potent effect it has on this feature. Figure 3 shows quite clearly that the production increases directly with the wind blown. With a blast volume of 45,000 cubic feet per minute for the first group, and 56,000 cubic feet per minute for the last group, an increase of 21 per cent was obtained from the increase in wind. Actually, an increase of 21 per cent in blast volume shows an increase in production of 21 per cent which serves to illustrate the close relationship between blast volume and production. To obtain maximum production it is necessary to maintain the optimum blast volume that the furnace will take.

Our standard blowing practice is to maintain the highest wind volume possible without making an abnormal amount of flue dust. One factor which it is felt has limited the amount of blast volume which a furnace can take has been the percent of ash in the coke. A reduction in the percent ash should produce a more open burden as well as reduce the amount of silica entering the furnace. With less silica entering, the furnace should operate with less limestone allowing more space for ferrous materials. Our studies on No. 5 furnace showed a better performance when operating with a lower ash-sulphur coke. We understand that some furnaces are operating with coke as low as 6 per cent ash, 0.60 sulphur, and maintaining a high rate of production and blast volume with low flux costs. This indicates that a good uniform coke is imperative for successful operation of the blast furnace.

It is interesting to note the similarity between Figure 2 showing the relationship of iron temperature and chemical analysis, and Figure 4 which shows the effect

Figure 4 — Relationship between slag temperature and iron composition.



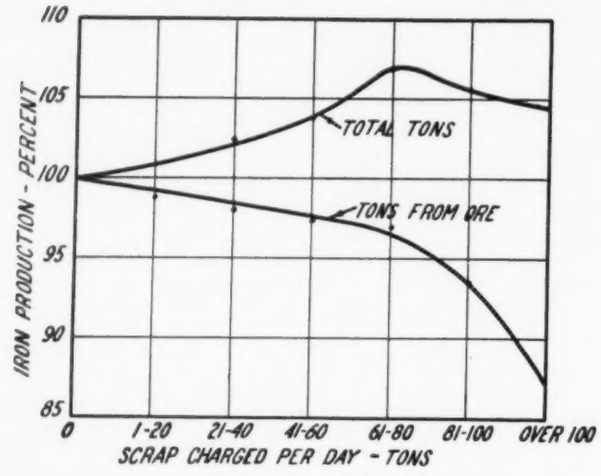


Figure 5 — Iron production reaches on optimum when 60-80 tons of scrap is charged per day.

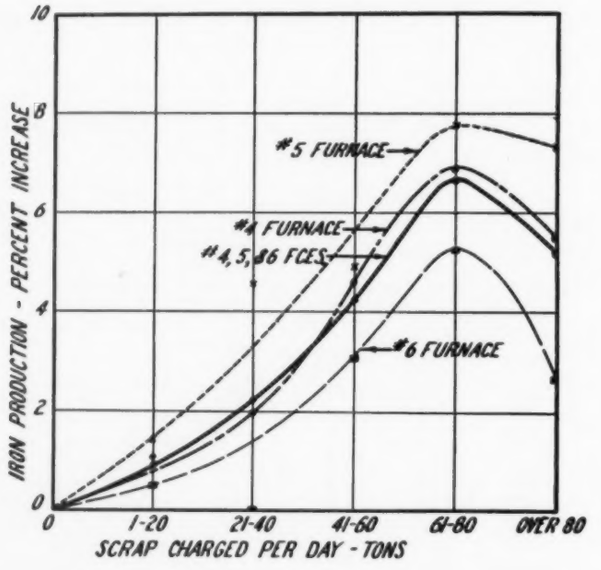


Figure 6 — Production curves for Nos. 4, 5 and 6 furnaces with varying scrap charges.

of slag temperature on silicon and sulphur content of the iron. The slopes of the silicon and sulphur curves compare quite closely for the two graphs, indicating a close relationship between slag and iron temperature. The slag temperatures have been determined with an optical pyrometer using an emissivity index of 0.40. McCaffery with others calibrated the optical pyrometer against a standard platinum-platinum rhodium thermocouple and found the temperature correction of blast furnace slag equivalent to that for a material whose emmisivity is 0.65.[1] On this basis the temperatures shown on Figure 4 are slightly higher throughout than the actual temperature. Since the slag temperatures obtained at the flush which is approximately one to two hours previous to cast, a means of forecasting the finished sulphur and silicon would mean that a change in the furnace operation could be made earlier than otherwise. While this change, in most cases, will be too late to correct the iron being cast two hours later, the change should be effective in more promptly correcting the difficulty. While a change in blast heat or blast volume will affect the iron being made currently, an ore change, coke blank, or limestone change will not effect the iron until 8 to 10 hours after the material is charged. Under such a condition it is necessary for the furnace operator to look ahead and consider the effect of burden changes made now on the furnace 2 or 3 casts hence.

The effect of scrap additions on production has been discussed pro and con for a long time. Since the amount of Fe per unit volume is higher for the scrap than ore charged, it seems logical that the more scrap added the more will be produced. This seems to be generally true; however, as shown on Figure 5 the iron production reached an optimum when 60 to 80 tons of scrap were charged per day. It will be noted, that although the production is somewhat lower with scrap additions greater than 60 to 80 tons, the production remains above the average rate of those days with less than 60 tons of scrap. Figure 5 also shows the tons of iron reduced from the ore alone. As expected, with increased scrap charges, the tons of iron reduced from the ore decreased. This relationship is due to the displacement of the ore with scrap, decreasing the amount of ore that it is possible to add as the amount of scrap charged increased. In this study, the casts were again limited to those with a blast volume over 52,000 cubic feet per minute. Further study on No. 5 and No. 6 furnace during the period June 1, 1942 to September 15, 1942 supported the results found on No. 4 furnace. Figure 6 shows the production curves for Nos. 4, 5, and 6 furnaces with varying amounts of scrap charged, and indicates the close relationship with an optimum production rate with 60 to 80 tons of scrap per day. No attempt has been made to evaluate the effect of the various kinds of scrap charged; however, that charged into these furnaces is generally a pretty good grade.

One of the many problems of blast furnace operators is to keep iron production up and sulphur in the iron down. The sulphur specifications submitted to the blast furnace require that the furnace be burdened with sufficient fluxing materials to produce a slag of sufficient basicity to remove the sulphur in the iron, since as already shown hearth temperature and also slag fluidity are effective. Most of the sulphur which enters the furnace arrives with the coke, and leaves the furnace in the slag and in the iron. Figure 7 shows the relationship between the sulphur in the slag and the sulphur in the iron. It is generally agreed that most of the sulphur removal takes place at the hearth as the drops of iron trickle through the slag. Kinney found that metal removed from the blast furnace just above the tuyeres contained 3 to 4 times as much sulphur as the iron at the cast.[2] Herty and Gaines conclude that most of the sulphur is removed while the metal is passing through

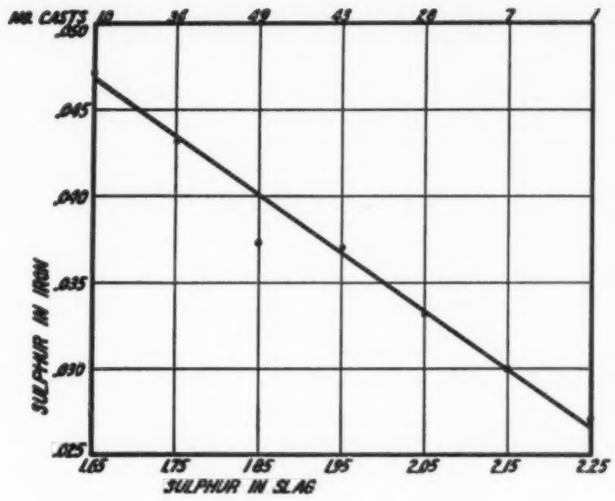


Figure 7 — Relationship between sulphur in the slag and sulphur in the iron.

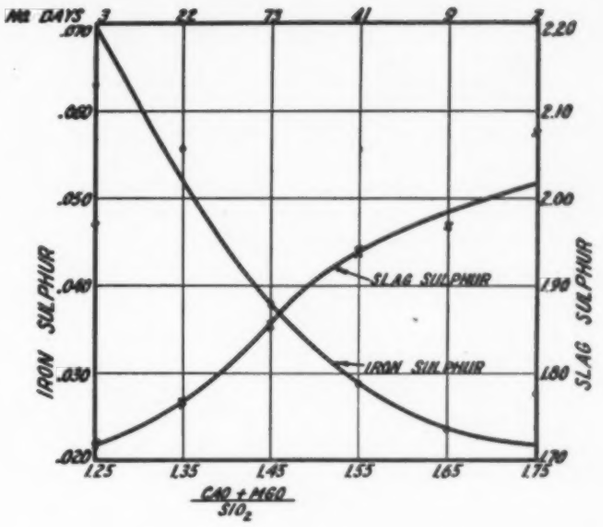


Figure 8 — Effect of slag basicity on sulphur removal.

the slag.[3] Just as in the open hearth, sulphur removal is very much dependent upon the basicity and fluidity of the slag. Joseph could not find any simple relationship by which chemical composition, termed "basicity", could be compared with desulphurization.[4] His work, however, referred to slags covering a wide range of composition. Our furnaces making bessemer iron are operating with a slag of approximately 10 per cent MgO and 8 to 9 per cent Al_2O_3, varying less than one per cent from day to day. Within these limits it is felt a direct relationship exists between basicity and desulphurization. Using the formula $\frac{CaO + MgO}{SiO_2}$, which is generally accepted as a fair measure of slag basicity, a correlation with sulphur in the slag and sulphur in the iron is shown in Figure 8. As expected, with an increase in the basicity of the slag, there is a decrease of the sulphur in the iron and an increase of the sulphur in the slag.

It has been thought that the desulphurizing power of blast furnace slag varies directly with molar basicity.[5] A study of the effect of the basicity on production and iron sulphur, using molar basicity to represent the chemical composition of the slag, indicated an increase in production of about 7 per cent when operating with a lean slag. The formula used to determine the molar basicity was as follows:

$$\frac{[\%\,CaO - (1.75\,x\,\%\,S \text{ in slag})] \div 56 + [\%\,MgO \div 40]}{(\%\,SiO_2 \div 60) + (\%\,Al_2O_3 \div 102)}$$

Each oxide has its own effect on desulphurization and the degree of the effect is not constant for all ranges of composition. Joseph has shown that Al_2O_3 cannot be ignored in computing basicity, as it is frequently done. Each acid and base has been divided by its molecular weight which partially corrects for the variation in basic or acidic properties of the oxides in the slag. The basicity was determined by the daily slag analysis reported by the chemical laboratory and is a composite sample of the slag at flush and cast. A correction for the per cent sulphur in the slag has been included, since some lime (CaO) is combined with the sulphur in the slag, as CaS, and the percent CaO reported by the laboratory includes all the Ca in the sample.

The study was duplicated on No. 5 furnace during a later period and while the studies were made on different furnaces both were making bessemer iron and operated on about the same burden.

Figure 9 shows the increase in iron production obtained on each furnace when the molar basicity was decreased. In both studies a gain of approximately 7 per cent was shown over the range of basicity indicated. The striking difference between the two tabulations, however, is the lower range of the basicity found on the No. 5 furnace study. During the study on No. 4 furnace only 32 per cent of the days had a molar basicity of under 1.36, while that on No. 5 furnace showed 64 per cent of the days within this range. This leaner slag, due primarily to the installation of coal washing equipment, played a larger part in the production records made during the latter periods.

The slag basicity on which the furnace can operate, to a great extent, is determined by the sulphur and silicon content of the raw materials being charged. Large fluctuations in these two elements prevent operating the furnace at the point for optimum performance since a range of safety is needed in case of sudden changes in composition. A reduction in the variation of coke quality and a reduction in coke sulphur has been achieved since the new coal washer

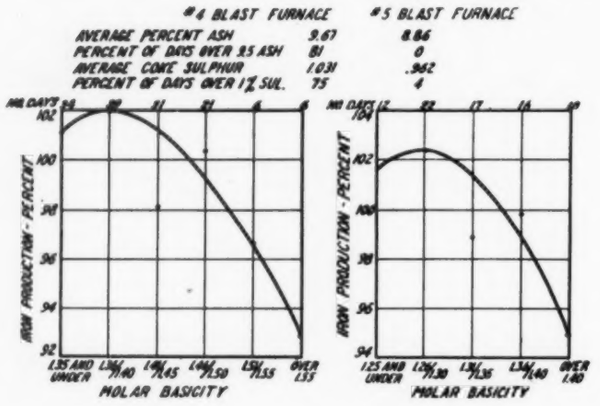

#4 BLAST FURNACE
#5 BLAST FURNACE
AVERAGE PERCENT ASH 9.67 8.86
PERCENT OF DAYS OVER 9.5 ASH 81 0
AVERAGE COKE SULPHUR 1.03 .962
PERCENT OF DAYS OVER 1% SUL. 75 4
IRON PRODUCTION - PERCENT
MOLAR BASICITY
1.35 AND UNDER
OVER 1.55
1.25 AND UNDER
OVER 1.40

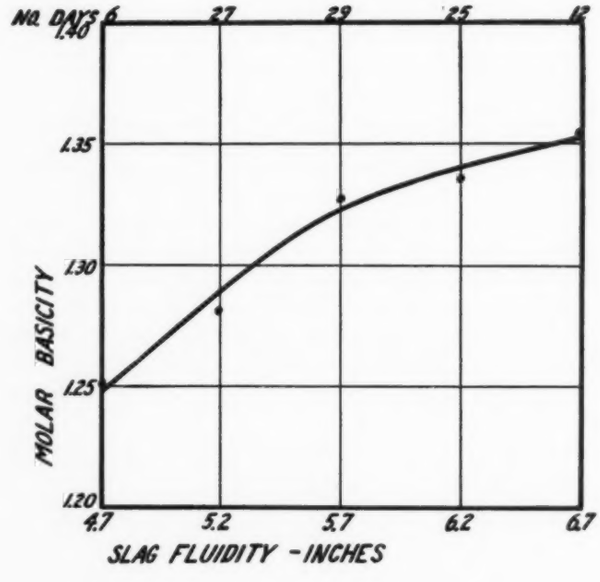
Figure 9 — Influence of slag basicity as measured by molar basicity on iron production of Nos. 4 and 5 furnaces.

was installed. A comparison of the coke sulphur and per cent ash in the coke during the two periods studied is also shown in Figure 9. The ash content was reduced from 9.67 per cent to 8.86 per cent and the average sulphur from 1.03 per cent to .962 per cent after the coal washer was installed. The percentage of days having a coke sulphur over 1.00 per cent was reduced from 75 per cent to 4 per cent, and the percentage of days with an ash content over 9.5 per cent was reduced from 81 per cent to 0 after the coal washing equipment was installed. The reduction in average values probably does not wholly represent the advantages by the coal cleaning equipment. The variation or spread of ash and sulphur content has been reduced appreciably. The by-product plant reports the ash to vary as widely as 3 per cent from day to day, and the sulphur over a range of .30 per cent for the unwashed materials. This variation in ash has been reduced to about 1 per cent and the sulphur to about 20 per cent. This reduction in ash content would also increase the carbon available for the chemical and thermal reactions of furnace operation. Another factor which must be considered is the effect of more extensive mechanical methods of mining and the reduction of the general quality of the coal being mined. An increase in the slate, ash, and sulphur can be expected and will necessitate the use of coal washing equipment to make coke which the blast furnace man can use profitably.

A study made in 1935 at our blast furnaces comparing washed and unwashed coal reported results definitely showing the advantages of such equipment; production was increased, coke consumption and flue dust were reduced, slag per ton of iron was less, and limestone consumption was lowered. The furnace moved more regularly and chipping losses on the resultant steel were reduced appreciably after the change. This study was conducted on No. 5 furnace, making bessemer iron. Such a study illustrates the importance of maintaining raw materials of good quality and uniformity to produce the greatest amount of quality iron. Other cases showing the effect of improved raw materials on iron production have been found from time to time. The use of iron ore concentrates, and the use of sinter are a few specific changes which have yielded increased iron tonnage. By taking advantage of ore preparation methods, screening and washing, the percent Fe in the concentrate was increased 2 to 3 per cent and the physical size of the ore was larger and more uniform. Test runs on the furnaces making bessemer iron and charging 100 per cent concentrates indicated an increase in production rate of 60 to 80 tons per day and a decrease in coke consumption of approximately 100 pounds per ton of iron. Another preparation of raw materials which should be considered is the sintering of the ore. A test run made on No. 3 furnace at Pittsburgh Works using 31 per cent New York magnetic sinter, analyzing 65.2 per cent iron and 3.6 per cent silica showed an increased production of approximately 100 tons per day and a coke consumption of almost 200 lb. reduction in per ton of iron. Increasing production by means of the selection and preparation of blast furnace materials is particularly timely since more iron is made using the existing plant facilities. While building new blast furnaces will increase iron production eventually, vital materials and valuable time, so essential at the present, are consumed by this methods.

Little mention has been made of the effect of slag fluidity on furnace operation and performance. The fluidity has been determined by the use of a viscosimeter measuring the flow of slag in a tube of 5/16 inch diameter. In sampling the slag at flush, a test spoon is cast into the viscosimeter and the length of flow is

Figure 10 — Relationship between slag fluidity and molar basicity.



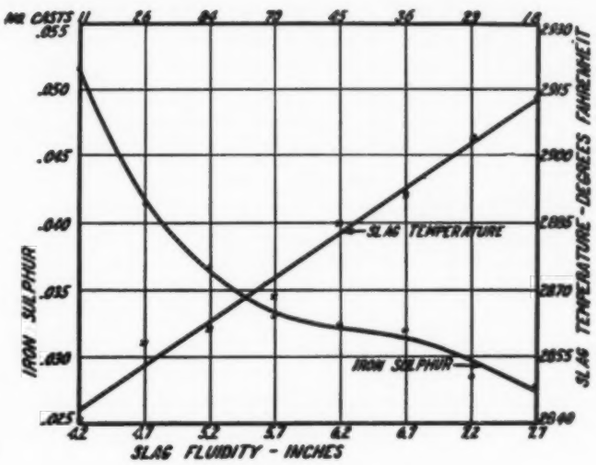


Figure 11 — Relationship of slag fluidity to slag temperature and sulphur in the iron.

measured by a rod inserted in the open end. In this method the length of flow actually measures a combination of slag fluidity, the reciprocal of viscosity, and melting point. The general relationship between slag fluidity as measured by this method and the basicity is shown in Figure 10. It will be noted that an increase in fluidity indicates more basic slag. The use of this method of determining basicity, however, is limited by the effect of slag temperature on fluidity. As shown in Figure 11, with an increase in the fluidity of the slag, the sulphur in the iron decreases. This decrease in the iron sulphur, however, might be due principally to the increase in the slag temperature also shown. Further study is being made to expand the use of fluidity and temperature to maintain a closer control of the furnaces. The importance of maintaining the furnace in balanced equilibrium is shown repeatedly throughout our study. Any undue fluctuation in one of these is sufficient to influence and upset the others since each is so closely related to the other. As pointed out by Graham and Work, the effect of a relatively small variation in ash content of the coke is accumulative in effect.[6] An increase in ash decreases the percentage of total carbon in the coke, and at the same time increases the weight of the slag formed; this in turn requires an increased amount of carbon to raise it to its melting point and then heat it to furnace temperature, thus reducing considerably the carbon available for other necessary chemical and thermal reactions of furnace operations. Further additional flux is needed which requires heat for melting and reduces the amount of ore which can be charged, thus decreasing production and increasing coke consumption.

While our work has barely scratched the surface it already shows that there are certain features, better knowledge of which will go far towards the production of more and "better quality" iron. Within the limits of our work to date the following items show promise of helping us attain our goal:

1. Maximum blast applied.
2. Lowest practical molar basicity.
3. 100 per cent washed coal for coke.
4. Close control of operating temperature.
5. Keeping scrap additions within the indicated percentages.
6. Most important of all, use of the best possible raw materials obtainable. In fact we might say, that in the main, the performance of any blast furnace unit will reflect the grade of raw materials used.

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American Rolling Mill Sets New Production Record for Pig Iron

▲ SETTING the seventh monthly production record in 13 months, the Hamilton division of the American Rolling Mill Company during April topped the previous monthly peak by 1,078 gross tons, L. F. Reinartz, manager of the division, reported recently.

The previous high, set in August, 1942, had been considered the ceiling for Hamilton's equipment.

"The performance of the Armco men at Hamilton is one of the most outstanding in the entire company's history," Reinartz stated. "It required perfect teamwork and infinite skill for them to top the previous so-called 'all-time' record, set last August, by such a broad margin."

The war production drive committee at the plant has wired Donald Nelson, WPB chief, "Hamilton Armco men are proud to report they have done it again — this time by 1,078 tons. We renew our pledge to you to consider pig iron production records merely as something to top in the future. Of course, the higher production records go, the harder it becomes to break them. However, we hope to have more good news for you as 1943 unfolds."

ADDITIVES IN

Petroleum Products

. . . . . the use of chemical addition agents in lubricants, thus modifying their properties, has developed rapidly in its short span . . . . . such additives now include film strength agents, detergents, inhibitors and oiliness agents . . . . .

by F. F. Musgrave

ASSISTANT DIRECTOR OF RESEARCH

THE LUBRI-ZOL CORPORATION

CLEVELAND, OHIO

▲ FOR purposes of this paper a petroleum product is taken to mean a fraction from crude oil processed by refining to serve in some particular application or group of applications. As such, a given product will have a group of properties more or less fitting it for the applications intended depending upon the nature of the crude from which it is derived, the attention given to the original selection of the particular fraction or cut and the refining processes to which it is then subjected.

Similarly for purposes of this paper an additive is taken to mean a chemical or a group of chemical materials added to a petroleum product in a substantially minor portion of the whole to enhance certain useful properties of a given petroleum fraction in service and to minimize or overcome certain defects and shortcomings which it would otherwise exhibit in its particular application.

HISTORICAL DEVELOPMENT

After the modern, as distinct from the ancient, discovery of petroleum some of its fractions were gingerly introduced as additives into the known and proven lubricants then in use for certain lubrication purposes. For example crude oil cuts were added to animal fats to provide longer service periods before drying out, carbonizing or other lubrication failures occurred. Crude lubricating oils were employed as diluents for pure acidless tallow oil from animal sources, at one time the accepted material for steam cylinder lubrication. Thus the raw material to which our modern additives contribute began life as an "additive" itself.

The existence of animal oils and mineral oils together in the same formulations soon led to the discovery that for certain purposes the combination performed better than either of the two separately. Thus a good many years ago lard oil and other materials were added to mineral lubricating oils to reduce the coefficient of friction with certain metal to metal combinations and early metal-working lubricants were frequently formulated on this basis. They are still with us for a limited variety of operations.

Metal working, with its high localized pressures, saw the introduction of the chemical, sulphur, into lubricants to provide anti-welding properties at the point of contact of the tool and the work piece. At first the sulphur was added in the powdered form simply by stirring into the oil. This was sufficient to show some improvement in performance and the principle of sulphur addition is widely used today although the sulphur is now added to oils in a variety of chemical combinations which contribute to the greater stability and effectiveness of the mixture.

In both of the examples cited the fact that performance in service was the criterion of satisfaction was of utmost importance. Better performance is a continual challenge in every field where materials give service,

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and two milestones in the progress of the internal combustion engine illustrate the development of the use of addition agents very well. The first of these is the use of anti-knock materials such as tetraethyl lead in gasoline whereby more horsepower per pound of engine and per cubic inch of engine displacement could be obtained than were possible when just gasoline was used. Tetraethyl lead controls the rate of combustion of gasoline to which it is added, preventing too rapid or explosive burning and promoting effective power conversion. This is now common knowledge.

The second illustrative milestone is the development of the hypoid gear for delivering the engine power to the wheels of an automobile. The use of this gear allowed the lowering of the center of gravity of the whole car body, permitting much smaller gears to be used for equivalent power transmission at apparently inconceivably high unit tooth pressures and thus made a considerable contribution to the advancement of automotive design. If addition agents of some type had not been introduced, the straight petroleum oils available would have prevented the introduction of this gear. Combinations of lead and sulphur and of chlorine and sulphur, and other groups of chemicals were developed and added in relatively small proportions with the result that these gears have since performed without scuffing, scoring or breaking down in service. The pressures have not relaxed but effective addition agents have been provided to allow the petroleum products to meet them.

Two other relatively early examples of the use of addition agents should be mentioned since both have had very general application in a wide variety of oils. The one example is the use of materials which reduce the pour point of lubricants containing wax thus avoiding the excessive cost of drastic dewaxing methods. The other is the use of materials which improve the viscosity index of oils, that is, lessen the rate of change in viscosity with changes in temperature. An ideal oil would have the same viscosity at all temperatures and would not solidify at the lowest operating temperatures; thus these two developments are important examples of the use of additives.

A certain diesel engine provides another outstanding example of the successful introduction of an additive into petroleum products. It was apparent that this particular engine could not operate satisfactorily under the difficult conditions where it could be most useful when lubricated with even the best quality petroleum oils available. Excessive carbon formation, piston and cylinder liner wear, ring sticking and varnish could not be avoided for even reasonable periods between overhauls. Eventually these conditions were very much improved by the introduction of a small percentage of a soap — that is, a compound formed by a metal with a organic acid. One explanation is that the soap in the oil behaved in some ways like a soap in hot water — that is, it exerted a washing action on the products of oxidation and contamination that the lubricating oil would normally accumulate and deposit in harmful places in the engine. Note that it did not necessarily prevent the formation of these potentially harmful decomposition products. The soap did, however, tend to keep these in suspension in the oil so that they could be removed by the oil filter cartridge or during the drain periods. Thus limited satisfactory operation was achieved at the cost of fairly frequent oil and filter changes. However this meant the difference between reasonably satisfactory operation and no operation at all so that it was a distinct advance, permitting in large measure the very rapid growth and use of this engine which has proved very useful under a great variety of operating conditions.

The soap-treated type of oil came to be called a detergent oil, from the primary function of the additive in it, and detergency in modern compounded oils is now defined and measured by laboratory and field tests in this same engine. That, however, is only part of the story. It became evident that newer bearing metals, designed for higher operating loads and speeds in internal combustion engines generally, tended to become corroded in service due to the action of acids formed by the oxidation of the lubricating oil and by outside contaminating influences. This fault became a problem of such magnitude that it required a solution either metallurgical or chemical. The chemical one provided an answer which permitted the continued use of these bearing-metal combinations which were otherwise so desirable. Inhibitors added to the oils in very small quantities prolonged the service life of these bearings by either retarding oil oxidation for a given length of time or by acting on the metal surface of the bearing so that it would not be so susceptible to corrosion by oxidation acids.

These two distinct types of compounded crankcase oils served in their respective fields with developments occurring in both inhibitors and in detergents and with quantity and quality of additive materials being varied to suit the needs of the service for which the oils were intended. The combination of these two developments added to one oil, produced the so-called all purpose crankcase oil which we know today.

This lubricant was assisted into being by developments in the equipment field producing diverse types of diesel and gasoline engines requiring emphasis on different oil properties. As a result oils are now available containing so-called multi-functional additives which provide a high degree of detergency with a maximum amount of bearing corrosion protection. It will be apparent later on that these oils occupy a prominent place in the present scheme of things.

GENERAL SURVEY OF PRESENT PRACTICE

If we consider the wide variety of petroleum products being manufactured there is ample evidence that the principle of adding something specific to the "pure and unalloyed" mineral hydrocarbons is being rather generally recognized. A brief and incomplete resume demonstrates that the following petroleum products have been known to benefit from the judicious use of addition agents.

1. Tetraethyl lead in gasoline as already mentioned.

2. Inhibitors to prevent deterioration of cracked gasline in storage for long periods have been successfully used for well over ten years. Very small quantities of active chemicals of the order of hundredths of a per cent are required.

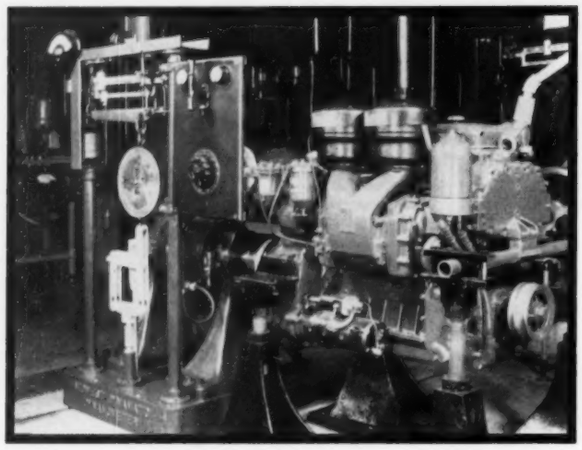

Figure 1 — Diesel engine, General Motors Model 4-71, used in specification testing of lubricants containing addition agents.

3. Diesel fuel combustion improvers or "dopes" are known which act in a manner analogous to lead tetraethyl in gasoline.

4. Inhibitors for transformer oils in less than a per cent concentration may prolong the life of the oil in service very markedly reducing sludge and acid formation.

5. Inhibitors for turbine oils, again in very low concentrations are now widely used to prolong the useful life of the oil in service and prevent scale and rust formation in turbine sumps.

6. Automotive oils are making increasing use of inhibitors and detergents as already outlined but scarcity of raw materials at present keeps this practice from becoming much more general.

7. Diesel engine lubricating oils contain addition agents in almost every brand sold for this express purpose.

8. Aviation oils have successfully incorporated additives in a limited number of instances although most aircraft oils in use are still of the straight mineral oil type.

9. Cutting oils of all types continue to be excellent illustrations of the use of additives.

10. Anti-rust or so called slushing compounds frequently are mixtures of chemical additives in petroleum vehicles.

11. Hypoid gear lubricants must contain addents as has been pointed out.

12. Asphalts for special purposes may contain addition agents to curb foaming on heating or other agents to allow roads to be laid down in wet weather or with wet stone or gravel "aggregate."

SIGNIFICANCE AND IMPORTANCE OF ADDITIVES

None of the above applications of addition agents were developed without there being originally an opportunity to do something better than available materials were doing it. There is always this opportunity so that the chemicals which are being used as additives now will undoubtedly be displaced later by others which will give even better performance characteristics to specific petroleum products as produced in the future. It goes without saying that petroleum refining has not stood still, waiting for addition agents to improve quality. The newest and best oils now being produced are much more stable than the corresponding materials of even comparatively few years ago. Similarly changes in design of automotive and diesel types of equipment have been very rapid latterly. The additive material may be regarded as simply a link in the chain which helps to keep lubricants and equipment together.

Perhaps it is in the field of automotive and diesel lubrication that the greatest advances in the use of addition agents have occurred in the past five years. Engines are in use by the thousand today which are efficiently lubricated only when additive type oils are used. Some types of engine with high power output cannot be run at all successfully on the best of straight petroleum oils. The Army and the Navy are now specifying additive treated oils for numerous special purposes and the Army has gone the full limit by purchasing only the best quality additive treated oils available for every internal combustion engine which it operates, at home or abroad. These compounded oils contain the so-called multifunctional or all purpose additives already mentioned, designed to give long trouble-free service under combat conditions where there is no service station around the corner.

THE TESTING OF ALL PURPOSE OILS

It might be of interest to sketch briefly the evaluation test program which an all-purpose oil must survive before it is approved for general use and distribution. Equipment manufacturers have played a large part in developing these test programs and oil companies and additive manufacturers (sometimes the same party in the latter instance) have cooperated.

The program begins in the chemical laboratory where a combination of chemicals or some individual configuration of elements in a chemical compound has been found to show promise by simple tests performed on a blend with a standard base oil. From this stage it goes to small engine tests under controlled laboratory conditions where careful analyses of both oil and engine condition can be made from time to time. After a few weeks or months of adjusting concentrations of the chemicals, modifying the formula if found desirable and possibly changing the make-up of the base oil, a satisfactory record is achieved.

The next stage is further laboratory testing on full scale engines, mounted on dynamometer stands in laboratories where the whole process is repeated. The same combination of additive and oil, having shown satisfactory results on these preliminary tests, then goes out into actual field service for some thousands of hours running under selected difficult conditions in commercial units. If this field test is satisfactory another laboratory test is arranged on a full scale engine of a different type operating at full throttle for the equivalent of 30,000 miles with no oil change. Again both engine and used oil are critically examined in

Figure 2 — General view of engine laboratory for testing addition agents in lubricants.

detail, and if this test is also satisfactory a fully approved oil is the result and it represents an all purpose crankcase oil. Additive containing oils which have gone through part but not all of the above program successfully may be said to have limited approval.

This general test program is very flexible in the early stages but whenever full scale commercial equipment is involved on actual approval tests the procedures are standard and minimum quality requirements must be met, with the engine being the final arbiter. It may be possible to have a successful test after which the oil looks very poorly while the engine looks very well, but the reverse would mean a failure.

One word about the flexibility of additive combinations with base oils. A new base oil with the original additive has to go through a complete series of tests to retain its status as an approved product as would a new additive combination in the original base oil. The reason for this follows presently.

THE NATURE OF ADDITIVES

From a cursory glance at the additive materials known to be employed in the various classes of petroleum products already enumerated it becomes apparent that certain classes of chemical compounds are widely used and furthermore that certain elements in the periodic table are singled out for frequent and on the whole, fruitful, attention.

Sulphur, chlorine and phosphorus and the metals, lead, aluminum, calcium, barium and zinc have been the most widely used elements in the additive field along with the ubiquitous carbon, hydrogen and oxygen of organic chemistry. Sulphur, chlorine and, to a lesser extent, phosphorus have been extensively used in the field of extreme pressure lubrication, e.g. cutting oils and gear lubricants while the metals have been most used as components of detergent compounds and some inhibitors. Sometimes the same metal-containing compound acts in both capacities. Inhibitors for mild types of service such as gasoline storage or transformer and turbine oil service have tended to be derived from phenolic type compounds and to some extent from nitrogen containing compounds.

These few things represent such an infinitesimal proportion of the total possibilities that it might be hastily assumed that fundamental chemical knowledge had thus already narrowed down the field of choice. Such is not the case. It has been written that "many are called but few are chosen" and this is definitely the case where the use of addition agents in petroleum products is concerned. The literature abounds with thousands of instances of materials developed and crystallized in the mind or eye of the inventor only to find that in actual practice they do not measure up to required standards. Either they do what they are supposed to do very well and in addition have some unexpected serious drawbacks in service or else they look well on paper but don't actually perform as planned.

By trial and error and through reasoning by analogy a small group of materials and combinations thereof have been painstakingly isolated, tested, used and found satisfactory in narrowly specific applications. An excellent additive in oil A may make oil B worse than it was by itself and this is a chief reason for extensive repeat testing each time either the oil or the additive in an "approved" combination has to be changed.

Such a thing as a universal additive which would make a superior lubricant for any purpose out of any and every possible base stock has been thought of but not very hopefully of late. There is no reason as yet to believe that this will ever be possible. Probably there will always be some oils more responsive to treatment than others and there will no doubt continue to be some whose numerous imperfections would far outbalance the strongest remedial measures.

Considered in the light of present knowledge, an addition agent suitable for one type of service, e.g., turbine oils, is not generally suitable for use in crankcase oils and the detergent type additive excellent in a diesel engine would be a handicap to a good turbine oil.

ADDITION AGENTS

CLASSIFICATION AND CHEMICAL TYPES

I. FILM STRENGTH AGENTS
- Chlorinated wax
- Chlordiphenyloxide
- Sulphurized fatty oils
- Methyl dichlorstearate
- Tricresyl phosphate

II. DETERGENTS
- Alkaline earth alkyl phenates
- Calcium dichlorstearate
- Metallic naphthenates, e.g. calcium, colbalt aluminum
- Salts of acids from oxidation of petroleum products

III. CORROSION AND OXIDATION INHIBITORS
- Phosphorus esters, e.g. triphenyl phosphite tributyl phosphite
- Alkyl phenol sulphides — polymer

IV. OILINESS AGENTS
- Esters of fatty acids
- Oxidation products from petroleum, e.g. esters of oxidation acids.
- Diphenyl benzidine
- Methyl salicylate
- Nitriles, e.g. stearoyl nitrile
- Ketones, e.g. stearoyl aromatic compounds

Changes in equipment may also require changes in additives, as exemplified by the development in bearing metals already cited.

The mechanism by which addition agents do their useful work is by no means clearly understood. In some of the simpler chemical systems where physical conditions are not subject to complex changes, e.g., gasoline storage, there are partially worked out hypotheses which agree to a limited extent with results obtained in practice. However as to the fundamentals of "why is a detergent?" and "what functions has a specific metal in some of the complex compounds employed?" we are almost at a complete loss. For the majority of applications of additive materials testing has shown that they work well as long as the conditions of service bear sufficient resemblance to the original test procedures. The whole problem of correlation of laboratory and engine test procedures with actual service conditions is much too lengthy and controversial for any attempt at resolution here.

THE OUTLOOK FOR THE FUTURE

For a new scientific art — not an artificial science, the development of the use of chemical addition agents has made rapid progress during the comparatively few years of its existence. The fundamental mechanisms governing chemical change are understood only through the use of tolerance hypotheses in relatively simple systems where comparatively few variables interrupt or distract the perspective. How much more difficult it is then to peer through the maze of largely unknown individual chemical compounds which exist in a lubricating oil fraction and determine just what additional chemical compounds should be added to nullify the trouble-causing propensities of some while bolstering the "staying qualities" and chemical stability of others. Obviously it isn't done that way yet, but eventually that may well become the procedure. Gasoline was once just gasoline, and very few answers were known to further questions which might have been asked. Nowadays an aviation gasoline of 100 octane number, or more, may be known to within a very good degree of accuracy as so much of one specific compound and so much of another. And the contributions of each to the performance as a whole can be fairly well judged.

Thus while we learn the "how" of addition agents in petroleum products we look forward to learning the "why" and to applying that knowledge as rapidly and as efficiently as is possible. A considerable amount of research is going on in this field and the outlook is for more and not less.

Gradually the rakes of chemical knowledge will sort over the enormous heaps of unknown facts waiting to be discovered in this field and they will be classified, evaluated and related to appropriate materials which will then be put to work where they can do most good. Further and more fundamental facts will continue to extend our views. None of us here will live to see the bottom of these heaps of unknown facts but that does not detract from our interest. What we know we make use of, what we don't know we try to find out. It is the same in every field where research is active but we appear now to be at a particularly interesting stage in this field of the development of chemical additives for use in petroleum products.

DISCUSSION

PRESENTED BY

G. E. REISER, Assistant Lubrication Engineer, Bethlehem Steel Company, Lackawanna, New York.

J. B. TUTTLE, Sales Engineer, Standard Oil Company of New Jersey, New York, New York

S. C. GRIFFITH, Lubrication Engineer, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania

W. H. MANDY, Lubrication Engineer, Texas Company, Pittsburgh, Pennsylvania

F. F. MUSGRAVE, Assistant to Director of Research, The Lubri-Zol Corporation, Cleveland, Ohio

C. E. S. EDDIE, Lubrication Engineer, Great Lakes Steel Company, Ecorse, Michigan

G. E. REISER: Mr. Musgrave's splendid paper throws a great deal of light on a mysterious subject. Additives to many of us are new. To Mr. Pecu, whom many of you know, additives are commonplace. For the past ten to twelve years we have been adding an additive to turbine oils. At present we add an additive to lead compounds, to stabilize and raise the extreme pressure qualities.

Heleshaw pumps on mudguns and Waterbury controls on flying shears gave us no end of trouble until an additive was used. Today we don't know what trouble is in connection with these units. This addition was made years before the general use was known. We have slowed the "cracking process" in the hot bearings of the benzol pumps with an additive in the oil.

At the time when refineries were attempting to stabilize the extreme pressure qualities of lead compounds we, after laboratory experimentation, stabilized our own with an additive. Today, after monthly checking, the film strength is higher than the original compound.

Thus it is today that our diesels, turbines, gears, etc., are serving us many more hours than before, thanks to the engineers in developing additives.

J. B. TUTTLE: We are pleased as a company, since we feel we are one of the pioneers in the additive field, to have the philosophy of additives presented as adequately as Mr. Musgrave has given it to you.

In the beginning additives were regarded as crutches. They were thought to be things a refiner had found to make a poor oil do as well as a good oil. That, I believe, was the early general user attitude, and unfortunately it is the philosophy which the refiner has had to live down.

The instances cited in the paper are, I believe, typical of the true philosophy which has motivated us who have studied the additive field. We are not simply

trying to put patches on defective material. We are trying to take the best we have and make it go farther. How well we can keep up with design demands depends entirely on how effective is the catalyst to which we find ourselves subjected at present — war.

I believe sincerely that additives are here to stay, and we hope this presentation has convinced you gentlemen that the philosophy of additives is not that of making an inferior material do better. It is making the best that we have go farther. Today our problem is to make more, faster, with less! I believe petroleum additives are helping greatly to do the job.

S. C. GRIFFITH: Mr. Musgrave has given us a very interesting history of the present use of additives in petroleum products. The story behind the development of these additives is left to our imagination. It is that story which stimulates our curiosity in the future of the subject. One phase of the subject which has been forcibly brought to our attention in the lubrication of steel mill equipment is the use of the lead naphthenate and to a lesser degree lead oleate additives to petroleum products. These combinations have successfully met conditions of extreme pressure and undue wear.

It seems that there is much to be done to determine the best method to combine additives with oils; that there is needed also, greater understanding of the effect of additives in any particular application. However, there should no longer be any difference of opinion as to the final value of additives in petroleum products.

That the opportunity shall always exist to better the performance of available materials should keep research active. It would be of deep interest to see the picture fifty years from now.

W. H. MANDY: Mr. Musgrave mentioned that when any change was made at all in the base oil, it had to be taken right through the research to see what effect it would have on the inhibitor, to determine the ability of the inhibitor to do the job that it was intended to do.

I wonder if he could tell us just what factors in the base oil would influence the effect on the inhibitors? There is so much comment on the mixing of the various oil company's inhibited oils because of the danger of upsetting the stability and effectiveness of the base oils and their inhibitors.

F. F. MUSGRAVE: Somebody said the subject was mysterious and that I had thrown light on it. I admit that it is mysterious, but I tried to emphasize that mystery rather than suggest that we know any fundamental answers.

It is perhaps wrong to consider an inhibitor or additive by itself. What is really significant is the performance capacity of a given additive when used with a specific base oil. Thus if a different base oil is proposed for use with a certain additive, different crude source, methods of refining or even a viscosity range change as the only variation from the original oil could upset the balance that previously had been found effective.

Addition agents are used in such a small proportion of the whole that if they are poisoned by the presence of small amounts of unknown or undetected unstable materials, the whole system might perform in worse fashion than if no additive were present; that is, reaction products of the additive and oil in use might be definitely harmful. We therefore have to look very carefully at any new combinations before they are pronounced satisfactory.

As for individual, specific reasons which would answer Mr. Mandy's question, we cannot supply them in the present state of knowledge of the subject.

C. E. S. EDDIE: This is a very informative paper on additives by Mr. Musgrave. The steel mill is a laboratory in itself for working out problems instigated by the research engineer in specific lubrication; its vital importance to equipment in our present period of demand is one of the most important that one can find in the industry today. It is a timely subject for presentation and discussion for us in the steel industry to develop the necessary facts, and to share the results of our individual efforts in effecting the best in production efficiency.

Better operation with a minimum operation cost is the challenge of the producing companies, wherever petroleum gives essential and indispensable service. It is a recognized fact that in modern equipment involving high unit pressures, additive agents must necessarily be used to meet specific requirements for the life of the equipment.

It is also desirable from a standpoint of mill operation, that wherever possible mechanically, to use a straight mineral oil. Inasmuch as I agree with the necessity and economy of using additive lubricants and providing extreme pressure characteristics in specific applications, Mr. Musgrave puts special emphasis on its use for diesel crankcase operation. Considering our steel mill, the switching routine for rolling stock does not call for additives or compounded oil. In this particular case, using a straight oil, during a two year period of continuous operation, with proper handling and purifying of crankcase oil, we have not been involved with troubles metallurgical, or mechanical.

This system of keeping the oil clean, consequently reduces the need for replacement parts, such as bearings, liners, rings, etc. We have found definitely that systematic removal of suspensions in the oil, also dilution, allow a free and uninterrupted schedule for diesel operation, and consequently prevents lost hours due to breakdowns.

It can be assumed that in submarine work where quarters are limited, additive oils could be used to some advantage; however on general principles, incorporating something in an oil to help carry suspensions of carbon, dust, fuel oil and water dilutions, as in the case of the mill transportation systems, will in my opinion promote excessive wear, and ultimately reduce the life of the equipment.

A clean oil to a high temperature-pressure diesel plant, is as beneficial as a clean blood stream to the human body.

Mr. Musgrave's paper brings out facts of history and uses that some of us may not be familiar with. Largely, as I see it, for the less severe uses as understood by steel mill engineers.

The field of heavy duty equipment, where the extremes of shock loads and heavy pressures on gears, and the screw downs of rolling mills, on which the greatest unit loads under the most severe mechanical conditions are involved, must also be served.

For such service, in addition to the heavier com-

(*Please turn to page 52*)

AIR POWER

The pressure of air upon the sail of a primitive canoe was undoubtedly one of the first instances of *air power* aiding man power. Centuries later, but still over two thousand years ago, man started to *compress* air to extend its use for practical purposes.

Through the years, the science of pneumatics has made possible much of man's progress. Today compressed air—*air power*— is essential in the performance of thousands of tasks, such as the mining, processing, and fabricating of the metals upon which we depend for our ships, planes, tanks, and guns. Air power and pneumatic tools are helping workers to improve their skill and to increase their production.

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Blast Furnace Charging Equipment

. . . . . B furnace at the Great Lakes plant represents modern practice in the application of blast furnace charging equipment . . . . . controls are such that the charging operation is automatic and foolproof . . . . .

by L. R. Milburn

ELECTRICAL ENGINEER

GREAT LAKES STEEL CORPORATION

ECORSE, MICHIGAN

▲ BLAST furnace material charging equipment is defined as that apparatus required to put ore, coke, limestone and other solid material into the top of a blast furnace. One unit of this equipment should also record and indicate the height of the furnace fill at all times. This equipment consists of the following units:

Large bell
Small bell
Bell hoist
Revolving distributor
Test rods, both manual and automatic
Skip car hoist complete with one or two cars
Coke screens
Coke weighing device
Scale car
Stock watering device
Indicating lights
Gas pressure equalizing equipment.

All of these units are closely interrelated to each other and must be so interlocked that they will function automatically and continuously to keep the furnace properly filled to as uniform a level as possible, without too much supervision on the part of the furnace crew.

These units can be operated either by air, hydraulic, electricity, or any combination of these sources of energy.

The operation of all these units at the new "B" furnace of the Great Lakes Steel Corporation blast furnace plant is by electricity.

Presented before A. I. S. E. ANNUAL CONVENTION, Pittsburgh, Pa., Sept. 22-24, 1942

BELLS AND BELL HOIST

The top of the furnace must remain closed at all times in order to prevent the escape of blast furnace gas to the atmosphere and, at the same time, the top must be so arranged that the raw materials of the charge can pass through the top into the furnace.

To perform these functions, the top of "B" furnace, as are many other furnaces, is equipped with two large conical castings in such a manner that they can be opened in sequence by suitable mechanism. One of these castings is called the small bell and the other the large bell. The small bell, in connection with the revolving distributor, is used to spread evenly the charge of raw material on the large bell as well as act as a gas seal when the large bell is opened to allow the charge to pass into the furnace.

These two bells are operated by a single unit, double drum, bell hoist engine. This hoist engine is driven by an adjustable speed, rheostatically controlled, direct current, 230 volt motor.

Mounted on the hoist engine shaft are two dogs which engage the two drums in such a manner that when the shaft is revolved in a counter-clock-wise direction from the neutral point to slightly less than 360 degrees, it will open the small bell. Returning the shaft to the neutral point allows the small bell to close by the aid

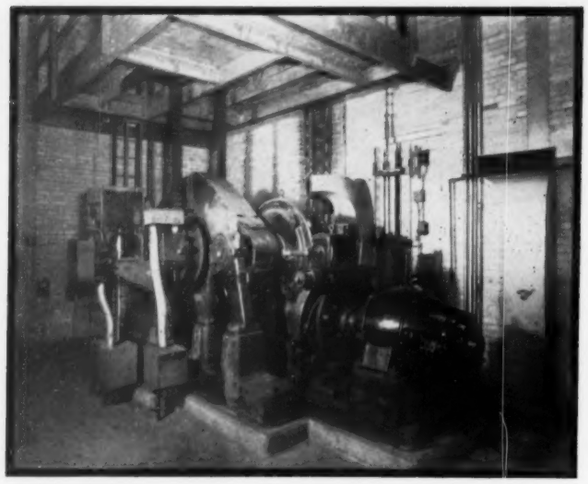


Figure 1 — This motor-driven double drum bell hoist operates both the large and the small bells.

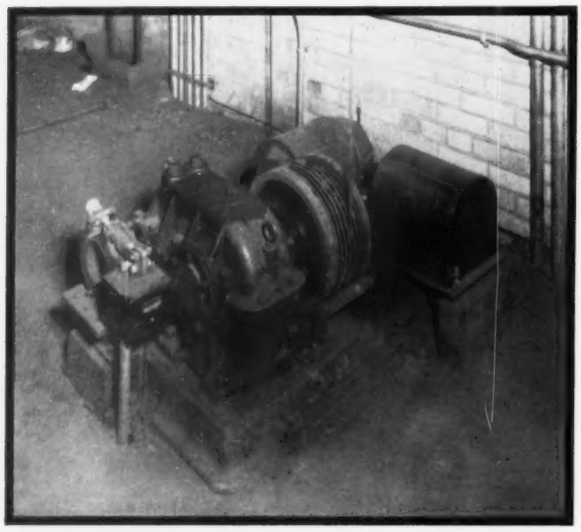


Figure 2 — The mechanism for operating the automatic test rods is located on a balcony in the skip hoist house.

of the bell counterweight. When the engine shaft is rotated in a clockwise direction from the neutral point the second dog will cause the large bell to open. This bell will, in turn, close itself by the assistance of the counterweight connected to the large bell beam. In this manner, the bells are operated independently from each other although both are operated by the same hoist unit.

Since the bell hoist is automatically operated, suitable timing devices, mounted on the bell hoist control board, are used to cause the bells to remain open a definite time. This time delay is necessary to permit all raw materials to be discharged from the bells before they are closed. On the large bell this time is set at about 13 seconds; whereas, 6 to 8 seconds is the usual time for the small bell.

The electrical circuit for the automatic operation of the bell hoist is set up in a roundabout way through limit switches, interlocks, relays and more limit switches thus:

A limit switch on the skip hoist actuates the revolving distributor. When this unit has completed its operation it sets up the control to operate the small bell. After the small bell operates a predetermined number of times, a mechanical counter limit switch, mounted on the small bell drum, will actuate the large bell. This mechanical timer limit switch will reset itself to zero after each operation of the large bell.

DISTRIBUTOR

The revolving distributor on "B" furnace is driven by a 19 hp mill-type motor. The function of the distributor is to distribute the charge of raw materials on the large bell so that these materials will pass into the furnace in a uniform manner.

The motor is located on top of the furnace while its control is located in the skip hoist house.

The distributor, which has the small bell as a bottom, rotates about the top of the furnace in 60 degree steps, and this type is known as the 6 point distributor. The skip car loads of ore, limestone and coke are dumped into the receiving hopper on to the small bell which is then rotated by the distributor to a certain point on the top depending on the sequence set up on the distributor control panel and there the load is discharged onto the large bell. The small bell dumps after each skip trip. The distributor can be set to rotate one step for each skip trip or any skip count up to 9. Likewise the large bell can be arranged to dump for each small bell operation or any small bell count up to 11 operations. As an example we might set up the sequence to operate as follows:

Six skips of material dumped on the large bell at the zero point, then dump the large bell; next six skips at 60 degrees point and again dump the large bell; so on around until we have completed the circle in 60 degree steps. With this arrangement we can fill our furnace in any manner we desire by making the proper setup on the distributor panel and the bell hoist panel.

TEST RODS

The automatic test rod is actuated by a small a-c motor operated winch located on a balcony in the skip hoist house. This rod can be operated manually or automatically. When operated automatically it follows the stock line of the furnace continuously and by means of a selsyn generator and recorders it makes two continuous charts of the furnace fill. It also acts as a furnace charge counter. One of the selsyn receivers is located in the pyrometer house and the other in the stock house. The latter is mounted on the operator's control panel. This rod can be operated manually by the stock house operator.

The manual test rod is actuated by a motor driven, push button controlled hoist that is mounted on the stock house coke scale platform. This rod indicates only by a pointer and calibrated scale. It is held up out of the furnace except when scale car operator desires to

Figure 3 — The single drum skip hoist is driven by two 150 hp shunt wound mill type motors under variable voltage control.

lower it for a check of the furnace fill as compared to that shown by the automatic rod.

These two rods enter the top of the furnace vertically through the top platform and they are located 180 degrees from each other. They are connected to their respective hoists by steel cables. With this arrangement the scale car operator can ascertain if the furnace is working down uniformly.

SKIP HOIST

The skip hoist at "B" furnace is equipped with two skip cars each of 200 cubic foot capacity and with both hoisting cables attached to one drum. The hoist drum is driven by two 150 hp mill type one hour rating motors with separately excited shunt fields, working through a suitable gear reduction unit. The gear ratio is such that at 560 rpm of the motors the skip cars will travel at a speed of 450 fpm and at this speed each motor on a 15 minute duty basis will develop 342 hp. Skip speed is adjustable from 75 to 600 fpm by the use of a variable voltage motor generator set.

Each hoist motor is directly connected electrically to a 150 kw variable voltage d-c generator. The two generators are rigidly coupled to a 400 hp, 440 volt, 3 phase, 60 cycle induction motor. The control panel for this hoist unit is so arranged that either generator can be connected to either hoist motor; likewise the hoist can be operated by either motor singly from either generator or both generators by merely operating certain knife switches on the control panel.

With constant field strength applied to the hoist motor the speed of the hoist is dependent upon the value of the voltage applied to the armature of the hoist motors. The value of the armature voltage applied to the hoist motor armatures is directly dependent upon the generator voltage; therefore, to vary the speed of the hoist we vary the field strength of the d-c generator. To do this latter we use small multiple field exciters. These exciter sets (there being one for each generator) consist of a miniature motor generator set of 1500 watt capacity. Each consists of a small 440 volt, 3 phase, 60 cycle induction motor driving a 1500 watt, 125 volt d-c 4-field generator.

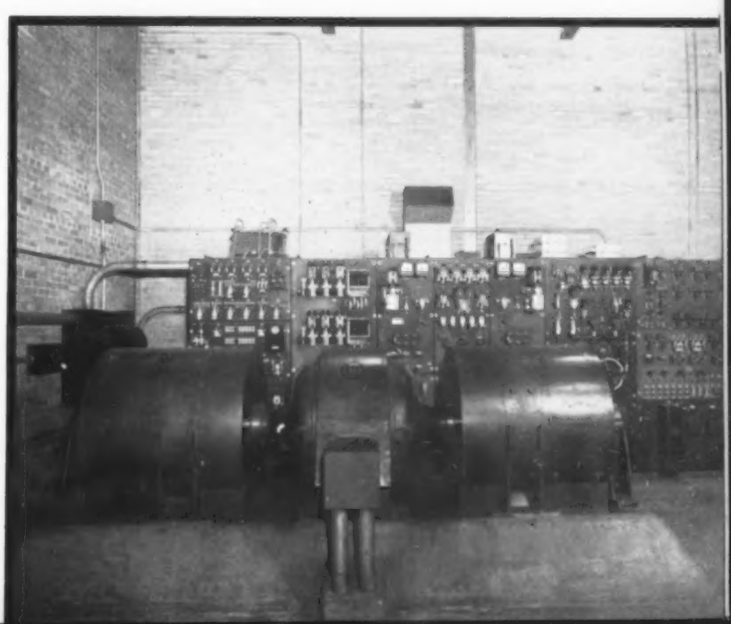
One field is used for stabilization to avoid "hunting" due to the rapid changes required for skip hoist control. The second field is used for current limit control. The third field functions as a load division control. The fourth or main field determines the polarity and voltage of the 150 kw generator.

The main field (designated as F-3) is connected through reversing contactors to two sources of voltage through directional rectifiers. The main voltage reference is obtained from a 440 volt, 60 cycle circuit through a saturable core transformer designed to maintain stable voltage even though the 440 volt a-c circuit should fluctuate as much as 20 per cent. This rectified reference voltage is compared to the voltage across a regulating resistance connected to the 150 kw generator terminals. The regulating voltage is determined by the selected value of the drop across the regulating resistance to which is connected the speed controlling contactors and the speed selector switch. Since the magnitude of the current in the regulating field of the exciter generator is of the order of four watts, the use of small capacity devices only are necessary in the controlling circuit.

The current limit field F-4 is similarly controlled from a reference voltage on the a-c line in comparison with the drop between the motor commutating field and the generator commutating field through proper directional rectifiers. Thus if the accelerating current or the retarding current exceeds a predetermined amount, which is adjustable, the current limit field, F-4, being in opposition to the control field F-3, will tend to hold the voltage of the generator down and in so doing will maintain practically constant acceleration and retardation.

The load division field F-2 is connected so as to be responsive to the drop across the commutating fields of the two generators. These fields, when the load divi-

Figure 4 — Power for the skip hoist motors is provided by this motor-generator set. The control board is composed, left to right, of one bell hoist panel, four skip hopper panels, a distributor control panel and a coke weighing control panel.



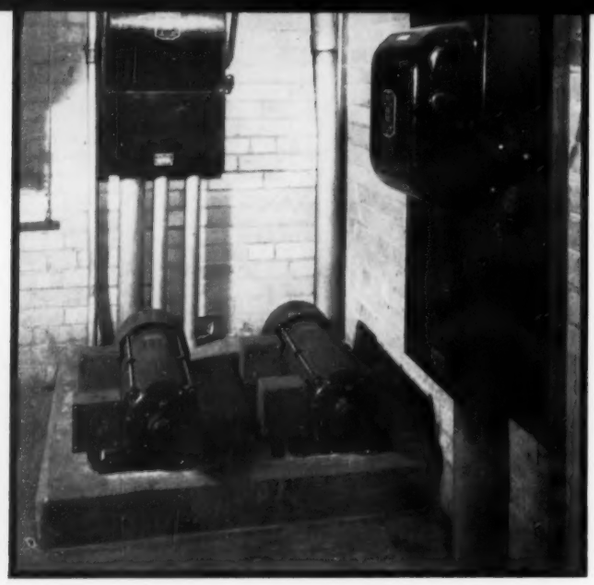


Figure 5 — Small multiple-field exciters are used to provide varying field strength in the d-c generators of the variable voltage control system.

sion is equal, will not carry current. As soon, however, as one generator is loaded up more than the other generator, one field will tend to raise the exciter voltage while the other exciter field will tend to lower it. By connecting the fields in this manner the speed regulation of the hoist will be substantially constant regardless of load.

The skip hoist can be operated manually from a master switch located in the hoist engine house, and can also be operated manually from a master switch located on the scale platform in the stock house or automatically by a push button from a control board located in the stock house where it can be reached by the scale car operator as well as by automatic preset in connection with the automatic charging of coke, by the scale car operator from the same control board.

COKE CHARGING

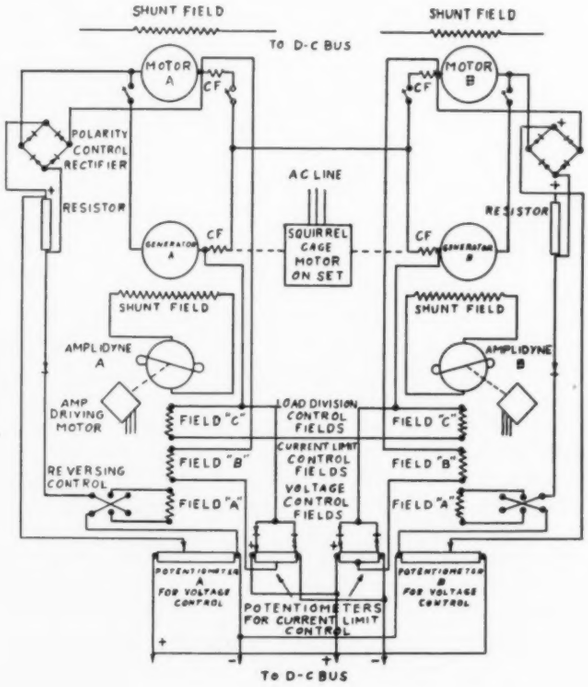
In connection with "B" furnace, we decided that we should be able to charge screened coke by either weight or volume. In order to accomplish this, a 6000 lb, 200 cu ft capacity weigh hopper was installed beneath each coke screen. These hoppers can be filled either manually or automatically from controls located in the stock house, where they can be reached by the scale car operator. When it is desired to fill these automatically the operator throws the transfer switch on his control board from "manual" to "automatic." This switch starts each screen motor and fills the hoppers. A limit switch located on the scale pointer will trip on full weight and stop the screens. There is an additional limit stop in the form of an electrode which is used on volume control and acts as a safety when screen control is working on weight filling.

The operator can now push the coke preset push buttons on his control panel. This will cause the proper weigh hopper to discharge into the skip car that is in the pit. When the hopper is emptied a no-weight limit switch in the coke scale will close the hopper discharge gate and start the screen to refill the hopper and also to set up the control to start the skip car to the top of the furnace with its load of coke.

The "automatic skip" push button is used by the scale car operator to send up skip loads of ore, limestone, scrap and other raw materials, including certain coke that may be charged other than that in the two coke bins.

The scale car operator's board is a sheet steel box about 2 ft 4 in. high by 3 ft 9 in. long (Figure 8), on which are mounted the necessary control push buttons, transfer switches, indicating lights and stock line recorder. All of these are necessary for the operator to properly fill the furnace. He can keep contact with the revolving distributor. He can charge coke by weight or volume. He can tell which skip car is in the pit by means of indicating lights. He can put a predetermined amount of water into his charge by a water charging switch. He has a continuous chart of the stock line recorder before him at all times which can also be checked by the operation of the manual test rod hoist. He can preset and send up charges of coke while he is away from the pit gathering other raw materials. This board should be seen to get a true value of what can be done in the way of charging the furnace. While it appears to be complicated, from the above discourse, it really is extremely simple and easy to operate. Through the wiring of this board and its control panel (located in the hoist engine house) each function is so interlocked that it is extremely hard for the scale car operator to make a false operation.

Figure 6 — Schematic wiring diagram of variable voltage control system for blast furnace skip hoist.



SCALE CAR

The scale car is electrically propelled and obtains the power from two overhead collector bars. The two car hoppers are air operated and a motor driven air compressor is mounted on the car to supply this air. The car is electrically interlocked with the skip so that the operator cannot dump a load into a pit when there is no skip car. This feature was thought advisable because the scale car operator cannot see into the pit and thus tell if the proper skip car is there ready for him to dump into. In addition to the interlock circuit he can also check the skip car lights on his operator's panel in front of him. The car is also electrically interlocked so that it cannot be moved with the hoppers open.

It might be well to run through a sample operating cycle of furnace charging at this time. We will start off by assuming a charge consisting of ore, ore, coke, coke, limestone, and we will set up the distributors to revolve after each skip load, or one point set up; while the large bell will be set to dump after five skip loads. Starting from rest we have one skip car in the pit and our scale car has two loads of ore in the hoppers. We have the operator's control panel set at "automatic." This means that our two coke weigh hoppers are full of coke.

Therefore, we dump the one scale car hopper and push the skip hoist automatic push button. The skip car starts up the incline. This will cause the small bell to open and then close while the skip is traveling to the top of the furnace. Should the bell fail to close, the skip will stop before it enters the dumping knuckle and it will remain thus until the small bell closes. Then the skip will proceed on into the dumping point. The distributor will revolve one step turning 60 degrees. We now dump our other pocket of the scale car and push the skip hoist button and then immediately push the two coke preset buttons. This being accomplished, we now proceed with the scale car to get our load of limestone. While we are away from the skip pit our second load of ore and two loads of coke will have been sent to the top and deposited on the large bell. When we return with our limestone, we will send it up as we did the first load of ore. When this load reaches the top and is dumped on the small bell the large bell will open and allow the charge to pass into the top of the furnace. Here we have left out one operation. Just prior to the operation of the large bell the automatic stock line hoist will lift the stock rod up out of the furnace where it will be protected while the charge is being dumped into the furnace. When the large bell closes, the stock rod will again be lowered into the furnace automatically. During the operation of the large bell the skip hoist, distributor or small bell cannot be operated.

There is one other small automatic feature about this furnace, namely the automatic coke breeze skip hoist, one for each coke screen. As the breeze skip fills up, it settles down into a saddle which in turn trips a limit switch and actuates the hoist, thus elevating the skip and dumping the contents into a coke breeze bin from which it can be put into railroad cars for transporting away from the furnace area.

The object of this automatic equipment was to speed up the operations of the furnace as well as to increase the quantity and quality of the iron produced.

These controls were put into operation about Dec. 1, 1941 and have functioned perfectly since that time.

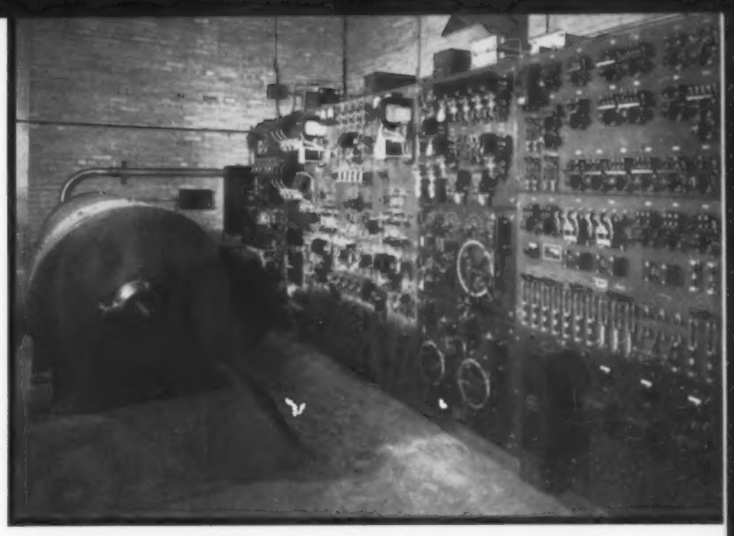


Figure 7 — Another view of the charging control board, showing coke charging control panel at right.

The electrical contactors on these control boards are handling such small currents that maintenance will be a very small item except for dust and dirt. To guard against dirt we have installed air cleaning equipment in connection with the ventilation of the motors and motor-generator set as well as the heating of the hoist engine house. We clean this air by the electrical precipitation method. This consists of passing the air through a high electrostatically charged area and thus causing the dust particles to become charged and to adhere to the oiled plates in this area which are then washed down frequently with water. After washing down the plates are then reoiled by spraying No. 10 oil over them.

So far we have said very little about the stock watering device. This unit consists of a 100 gallon capacity open end water tank in which there are five various length electrodes. Each of these electrodes can be adjusted so as to allow a definite quantity of water to flow into the skip car. The quantity is selected by the

Figure 8 — This control panel gives the scale car operator complete information and control of furnace filling.

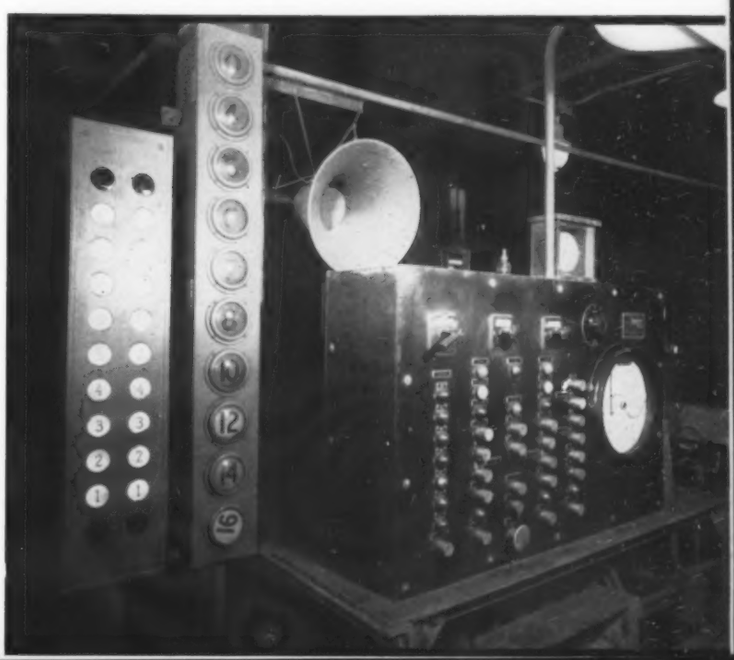


Figure 9 — An automatic skip hoist removes coke breeze from each screen, dumping the breeze into a breeze bin. Note slack cable limit switch in foreground.

scale car operator by means of a water charging selector switch calibrated in gallons. This switch is located on the operator's panel.

When the water push button is manually operated, it energizes the motor-operated valve, which in turn opens the discharge to the tank and allows the selected amount of water to flow into the skip car. The amount of water is determined by selecting a circuit through the proper length electrode, which acts as a limit switch to close the valve as the water leaves the point of the electrode. The tank then automatically refills itself ready for another charge.

So far we have found no occasion to use this watering device.

Also in the stock house we have the following indicating lights: lights for the big bell, showing when it is open and closed; lights to indicate the position of the revolving top, lights showing which skip is in the pit, lights showing the height of fill of the furnace, lights indicating the last move or set up made on the control board as well as lights indicating power on the control board.

With all of these interlocks, lights and indicating devices it is almost impossible for an operator to make a false operation.

There is one other automatic feature on this charging apparatus that I have failed to mention and that is the gas equalizer. This is a device to equalize the gas pressure between the bells and is so wired that it can be interlocked with the operation of the large bell. However, we have found that this device, like the stock watering device, was not required at this time, but both of these units are so mounted and wired up that they can be put into operation at a moment's notice, should we find that they are required.

With this automatic control, our scale car operator is able to send up from 10 to 12 charges per hour with a skip car speed of 450 fpm while operating on a charge of two ores with lime mixed and two cokes.

MUSGRAVE *Discussion*

(*Continued from page 45*)

pounds mentioned by Mr. Musgrave, there are available special lubricants of three types: (1) fibrous structure, (2) chemically compounded, and (3) chemically treated, — all distinctly different types of super extreme pressure lubricants, the uses of which have been demonstrated for some years past. These are generally found in heavy bodied cylinder types of oils in various degrees of flowing plasticity, as well as extreme pressure oils that flow freely below zero.

In this paper, Mr. Musgrave refers to the additives for the several purposes listed, while it is pointed out that the different kinds of mineral oils made from the various crudes must be considered individually; in most, if not all of the references, it is stated that the additives are incorporated directly into the mineral oils, either separately or as mixtures of the two or more used. That is undoubtedly the simpler procedure for the average requirement.

Our interest has recently been directed to lubricating products in which the additives are introduced in a vehicle of a colloidal character, or a suspending metallic base compound. These particles result in more uniform dispersion and better stability. We have seen these products demonstrated in other mills, and are now employing them in our operation. We expect to investigate their values further as the records show that the lubricants require much less frequent application, and the cost of both labor and lubricant are materially reduced.

F. F. MUSGRAVE: I have no comment to make on Mr. Eddie's discussion beyond the fact that I cannot entirely agree with his general views on diesel engine lubrication. For example, we have not seen any evidence to show that the use of modern addition agents in heavy duty diesel oils will promote excessive wear and ultimately reduce the life of the equipment. Naturally systematic purification and change of any oil, whether treated or untreated will extend the efficiently useful period of life of any mechanical equipment. It is not clear, however, why Mr. Eddie should believe that his system of periodic removal of suspensions, etc., is definitely superior to continuous protection from the formation of deposits in potentially harmful places in an engine such as is afforded to a degree throughout the service period of a modern diesel crankcase oil incorporating a detergent together with inhibiting action. Admittedly an oil change period is required whether the straight oil or a treated one is used — though this is not necessarily after the same number of service hours in both cases.

Bearing Surfaces

. . . . . the development of sensitive instruments for the measurement of surface roughness has encouraged research on surface finish . . . . . tests have shown that a great part of our bearing difficulties are attributable to specific defects of surface . . . . .

by E. L. Hemingway

INTERNATIONAL MACHINE TOOL CORP.

ELKHART, INDIANA

▲ PROBABLY the most serious mechanical problem that we have to contend with is bearing trouble. To fulfill the demands for better bearing performance, we are producing dimensions so precise that our ingenuity is taxed to measure them correctly. We employ the finest steels and bearing metals that we know how to make; yet we do not get the desired results. Undoubtedly, further improvement will come with better combinations of metals, and with more critical attention to lubrication. Yet, because abrasion, galling, and other bearing ills, must originate on the very outside dimension of the bearing, it is obvious that a closer examination of minute surface conditions offers a very real prospect for substantial improvement.

So many factors are influential in the operation of bearings that it has proved difficult to place the proper values on the effects of variation in surface finishes. In fact, only in very recent years has any wide-spread attempt been made to investigate thoroughly the characteristics of ground and otherwise machined surfaces.

The progress of commercially applied mechanics has always depended upon practical means of measurement to determine results, and to compare one man's work with that of another. Consequently, the development of such instruments as the profilometer and Brush analyzer for the measurement of surface roughness has encouraged research on surface finish to a considerable degree.

It has been my good fortune, during the past four years, to have the use of both of these instruments, as well as other equipment necessary to the critical examination of surface conditions. Over this time, nearly two thousand bearings of various kinds have been submitted for recommendations as to possible improvement. From these observations, I believe that the specific defects of surface, which have been the cause of a very large part of our bearing difficulties, are easily described. The equipment and processes available at this time, have made the definition of surface defects reasonably complete.

It appears that defects of surface can be divided into two classes: first, those of the metallurgy of the surface layer; and, second, those of the contour and shape of the surface, — in other words, its geometry.

These geometrical defects can further be divided into two kinds: first, the very short pitch ridges created by a turning tool point or grinder grits, with the appearance of which we are all familiar; second, a longer pitch waviness caused by machine tool inaccuracies. Examples of waviness produced by grinders are feed spirals, chatter, and flats. Centerless ground parts average much more deficient than those ground on centers. Other types of machine tools almost invariably produce more serious defects than grinders. We have found very few surfaces, produced in any manner, that did not have one or more varieties of long pitch defects.

The metallurgical defects can likewise be divided into two sub-divisions: first, the fragmentation of surface, due to the violence with which all machine tools remove a chip; second, those detrimental conditions produced by the heat developed in grinding. These are annealing of treated steel surfaces, and production of semi-amorphous or "smear-metal."

With reference to fragmentation, it is well known that metal is not cleanly cut off by a turning tool; instead it is torn or split off at some distance ahead of the tool point. Consequently, the resulting surface is covered with partially loosened minute splinters of metal. Not only is this true, but the crystalline structure is distorted to some depth beyond that of the deepest tool or grit marks. An illustration of the splintery nature of ground and turned surfaces is the rapidity with which

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they rust as compared to those made smooth without fragmentation. Moisture is retained on the fragmented surface through capillarity.

Referring now to the heat developed in grinding; Bowden, Wolff, and others, have reported that momentary temperatures in excess of 2000 F prevail at the line of contact between the wheel and part surface. Ofttimes, in an attempt to secure an unusually fine surface by the use of a hard, fine grit wheel, the metal actually is made plastic and is flowed from high points to fill in low ones. Such "smear-metal" is brittle, and has little real attachment to the parent metal. It is easily spalled off under high pressure.

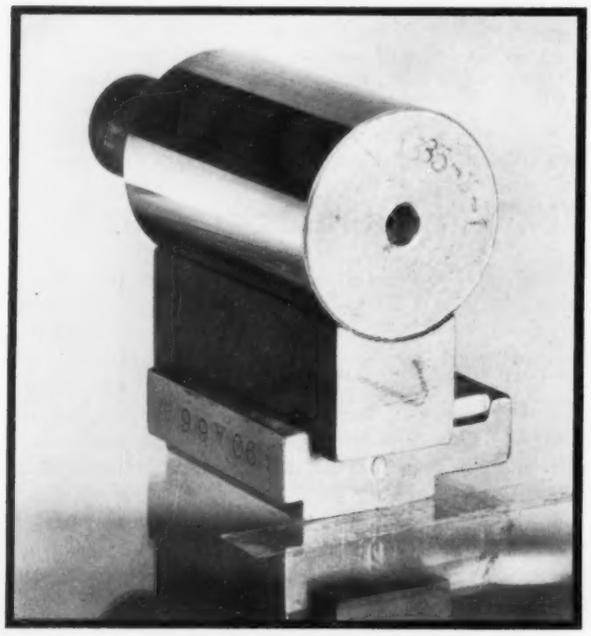


Figure 1 — A superfinishing stone and stud to which it has been applied. Shows area of contact, which acts as a master surface to reveal pattern of surface defects by contacting high points only, at first application.

The commonest and most important effect of grinding heat is the annealing of a treated steel surface, and this occurs to some extent in all grinding of such parts. Perhaps the depth of this annealing is most often very small, yet I have often found it to be deep enough to be measured easily with micrometers, especially on surfaces ground to a low profilometer reading. Where annealing has proceeded to such depth, the measurement is taken by removing the soft skin with a file over a sufficient area, then miking over this new dimension, and comparing it with the original diameter. A peculiarity of the exposed surface is that it is warty or nodular; the annealed depth is not uniform. In the best of grinding, I believe that the tip of the ridge, at least, is always annealed, sometimes also decarbonized, in the case of treated steel parts.

Briefly then, the things that cause the different defects of bearing surfaces are as follows: first, the usual single direction of stock removal, resulting in the formation of a more or less continuous helical ridge by the turning tool or grinding grit; second, the violent action of a tool capable of removing considerable metal, with fragmentation, annealing, production of smear metal, and possibly decarbonization of the ridge tips as a result; third, the inability of the machine tool, including grinders, to produce a sufficiently accurate geometrical shape.

Before turning to the discussion of the effects these surface conditions have on bearing operation, we should recognize the differences which exist between truly fluid and boundary lubrication. During full fluid lubrication, moderate variation in surface roughness is important for little more than two reasons. The first is agitation by roughness, and consequent heating of the oil film, which very often is an important item; second, an increase in clearance may be necessary because of greater roughness.

However, in practice practically all bearings do operate under boundary or deficient lubrication, at times. There are few, for instance, that are not shut down from time to time. During these periods of idleness the oil film may be squeezed out, and upon restarting, until the speed of rotation has built up the film pressure, we do have faulty lubrication. Other bearings, such as crankshafts, are subject to repeated shaft deflection or misalignment because of variation in load. Reciprocating bearings are difficult to lubricate efficiently, because the stoppage of motion at the end of the stroke drops the oil film pressure. Still other rotating bearings operate at slow enough speed, or at high enough pressure, to make a fluid film next to impossible to maintain. Without question, there is a wide variation in the severity of operating conditions, yet, from the practical standpoint, this is more a matter of degree, than a sharp difference between fluid and boundary lubrication.

If all bearings do come, at least occasionally, to approximate metallic contact, then surface finish and surface shape must have an extremely great influence on bearing life. Very minute surface conditions have an influence far out of proportion to their size.

The two major effects of these detrimental conditions are abrasion and galling. The extent of damage, and the exact manner in which it is done, varies with the combination of metals in the shaft and bearing. The probability of galling is much less with a hard steel shaft and a babbitt bearing, than with a soft steel shaft and a soft steel bearing, yet it is always caused by clean metallic contact. Abrasion will usually proceed quite differently with these two combinations of metals, but its origin is release of metallic particles, almost invariably. The effect called scoring may be due to either or both of these actions.

Damage by abrasion starts with interlocking of geometrical defects on the newly machined or ground surfaces. As ridges on the shaft come into contact with similar ridges or other inequalities on the mating surface, the most simple result is the flattening down or pushing aside of these irregularities. Unfortunately, this action is invariably accompanied by the release of fragmented particles. These may circulate between the surfaces with the oil, or may become more or less deeply embedded in the softer surface.

Where the bearing metal is quite soft and the shaft comparatively hard, the particles very often become almost completely embedded in the soft surface, and it

then acts as a lap. As such particles are accumulated, the wear is transferred from the soft surface to the harder. It is generally believed that babbitt bearings are insensitive to surface finish on the shaft. This is not exactly the case. Particles will become so deeply embedded in this alloy, that only enough of their tips project to smooth the shaft rapidly and thus improve the operation. The tendency is to improve the geometrical shape of the shaft, also, but this may be offset by regularly spaced, intermittent loads, which may tend to produce an oval shape instead. Due to this capacity to embed, babbitt bearings are seldom seriously scored, nevertheless, the lapping will proceed continuously, under boundary lubrication, and the clearance will eventually become excessive. A shaft without these original defects of geometry and fragmentation would operate still more satisfactorily.

When a harder bearing metal, such as bronze, is used, the particles seldom become so deeply embedded. Instead, experience has shown that they remain in the lubricant, causing erosion, and become wedged between the two surfaces, embedded just deeply enough to hold them in place. They have little tendency to produce smoothness; scoring is more often the result. Soft steel shafts are seldom run successfully with bronze bearings, under heavy duty. The usual, and most practical remedy is to use one that is hardened. Scratching, scoring, and galling are thus reduced to a minimum.

These two combinations of metals briefly illustrate the varying action of abrasive defects. In soft metals, they tend to become embedded, often increase the shaft smoothness, but continuously abrade it in a comparatively mild way; with harder bearing metals, there is a tendency toward serious abrasion and scoring.

However, because a certain pair of metals for shaft and bearing have been specified, is no guarantee as to just what sort of abrasive action will result. Much depends upon the lubricant, and the method of its application. There is a vast difference between occasional squirt can oiling and filtered, pressure lubrication. Extreme bearing pressure can cause rather deep embedding even into a bronze surface. This often happened in the older automobile king pin bearings, when the bronze bushing would outwear the hardened pin. Annealed and fragmented metal was loosened, and too infrequent flushing out by addition of lubricant allowed such particles to become firmly fixed.

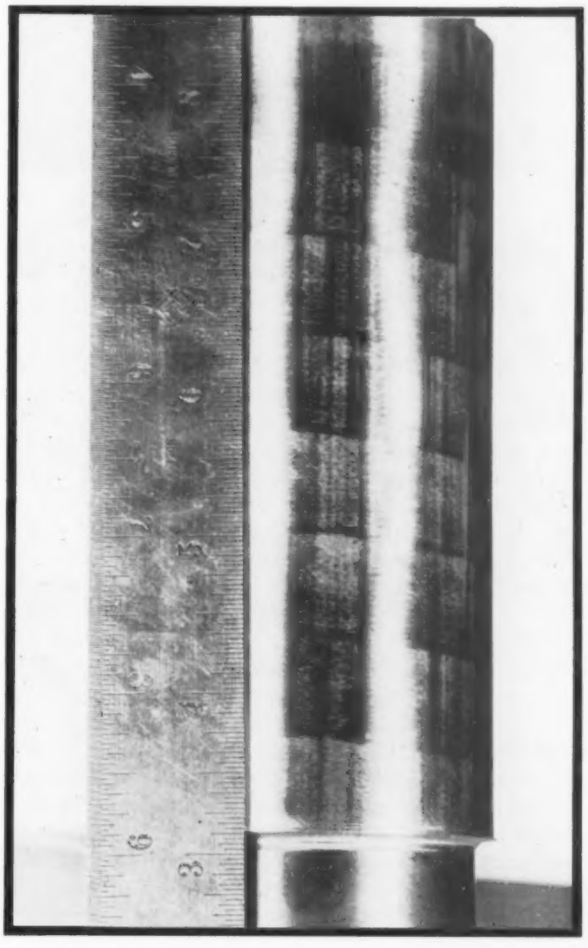
Surface damage caused by interlocking of short pitch defects, usually grinding ridges, will certainly be aggravated by longer pitch waviness. Perfection in geometrical shape (together with the minimum in clearance) seems more necessary than any other feature of surface finish. This may be a debatable point, because there is no readily available means by which ridge and waviness depth can be compared. Neither the profilometer nor Brush analyzer give any indication of long pitch waviness. However, if the ridge depth does not exceed that normal to good grinding practice, I believe that waviness is more detrimental than ridges. We must recognize the fact that waviness, because it introduces projecting promontories, not only accentuates the bad effects of the other defective surface conditions, but greatly reduces the effective bearing area.

The bearing is designed with a certain extent of area because it is believed necessary to carry the load involved. If waviness is present, the load is borne on its highest points, and the pressure on these points will be greatly in excess of calculations. Tearing away of the ridges is not likely to be the complete effect. During the wearing-in of the bearing, the ridges on the high spots not only act as dull tools to cut the mating surface, but will eventually be worn away themselves. As such a comparatively smooth spot first appears, the other major effect, galling, may become serious.

Most competent authorities now believe that galling is really a welding that takes place between the shaft and bearing metal. It is no longer thought that heat is necessary for such welding to occur, although it usually is present, and does assist in that action. Three conditions must be in effect for galling to take place. The metals must have some degree of affinity for one another, which all bearing metals do have to varying extent; their surfaces must be absolutely clean; and they must come into sufficiently close contact that the surfaces are within their mutual field of molecular attraction.

Often, just before a bearing galls, some area of its surface, usually quite small, is subjected to intense

Figure 2 — A diesel locomotive transmission shaft superfinished just long enough to show pattern of high spots. The normal grinding ridges, feed spirals, and flats due to a loose grinder spindle, are plainly visible.



localized friction, which produces heat. The heated spot expands, it becomes higher with relation to the balance of the surface, also more plastic. Because it is softer, it is more easily deformed to a larger area of contact, and the combination of heat and increased pressure make it comparatively easy for all contamination to be wiped off, thus fulfilling the necessary conditions for serious galling.

If the bearing metal has low fusion point, "wiping" is likely to result through actual melting of part of the heated spot. With the use of a good bearing metal, such as babbitt, heat is less likely to develop because of its low affinity and coefficient of friction, and some capacity to flow even in the cold state, thus reducing the size of the high spot. If the metal is a harder one, such as bronze, heating will stop the shaft rotation long before melting could take place. A high percentage of lead is sometimes added to bronze to prevent galling and scoring when lubrication fails. The lead does not alloy, but is dispersed in globules throughout the metal. As heat is generated, I believe the surface lead melts, and the minute amount thus released partially oxidizes and acts as a contaminant to prevent galling.

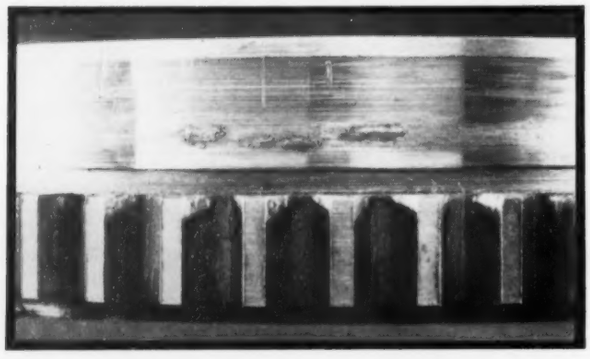


Figure 3 — A galled bearing surface. Shows spots where welding has occurred. Particles of metal have thus been torn from one surface to become ragged defects on the other.

While the tendency toward galling is increased by heat, we should not overlook the fact that it is entirely possible, under very low speed of rotation, if the required cleanliness and close contact are obtained. In fact, except for the expansion due to generation of heat by high surface footage, the conditions obtained under low speed of rotation are more favorable to galling than otherwise, as fluid lubrication is maintained with greater difficulty.

In addition to abrasion, a usually mild form of galling is caused by interlocking of surface ridges. Small areas are wiped clean enough to gall more often than is commonly supposed, and much of the effect called scoring is due to this cause. Such welds are usually minute enough that they instantly break loose, but a particle of metal is thus torn from one surface to become a ragged defect on the other. Abrasion eventually wears it off, but a scored ring is left on the mating surface, which varies from an invisible size to one that is serious.

When hardened steel shafts are used to reduce galling and abrasion, one of the most troublesome, and often unsuspected conditions, is annealed ridges due to grinding heat. These ridges, since they have become softer, are more easily deformed to sufficiently large areas of contact that noticeable galling and scoring occur. Galling is a three dimensional condition — it involves both area and depth. Soft and ductile metals will allow the tearing-out of particles to a comparatively large depth; hard metals will flake off in very thin particles. Steel shafts with truly hard surfaces thus tend to remain smooth much longer than soft ones, but very disappointing results will be had if they have been annealed. Tests made at our plant, of hardened shafts with all grinding ridges removed, and run against bronze bearings, show remarkable results as compared to those secured with a well ground shaft. The life of a truly hard and smooth shaft will be many times that of one with only very slightly annealed ridges.

There has been a considerable trend toward the removal of ridges by various methods of polishing which do not remove waviness. In fact, they more often increase it. While polishing undoubtedly reduces the interlocking of surface defects, and thus decreases abrasion, it does not produce the most desirable results as far as galling and scoring are concerned.

While smooth waves are more difficult than ridges to force through an oil film into metallic contact, when it does occur the results are liable to be much more damaging. The smooth contact will have a much larger area, and the weld will be correspondingly large. The greatest difference between this condition and that obtained by the complete wearing away of ridges on a high spot, previously referred to, is that polished waviness has a controlled degree of smoothness. A surface that is both polished and of perfect geometry will be almost impossible to force into metallic contact in the presence of any appreciable quantity of lubricant.

If we are to reduce this tendency to gall, two things must be done. We first must decrease waviness to the limit of our capacity. Second, some system of minute oil grooving over the entire surface must be provided, to insulate the two surfaces from clean metallic contact, as well as to lubricate.

Oil, particularly under boundary conditions, has two functions. It not only acts to reduce friction, but, from the galling standpoint, is a contaminant as well. Actually, dirty oil is more apt to be the cause of surface cleanliness, because the grit contained therein may scrub off surface films, making clean metallic contact more probable. Grit also may score, raising metal ridges above the mean bearing surface into increased contact.

The most efficient pattern of these minute oil grooves, for each variation in bearing conditions, is a problem that offers the most important field for research on bearing surfaces that remains. Improvements in lubricants and in bearing metals, at present unknown, will undoubtedly be made; but, as far as bearing surfaces themselves are concerned, the necessary conditions already seem clearly defined, except in this respect.

As further work is done toward the solution of this problem, we shall undoubtedly find that certain definite patterns are most successful. At the same time, we may find that practical difficulties of production will force us to accept some variation from those patterns. We

therefore will need to know the facts concerning all kinds of surface patterns.

At the present time there seem to be two ways by which oil pockets can be produced that will not result in serious abrasion by interlocking of irregularities, and will remain effective after a reasonable wearing-in period. Both of the methods to be described depend upon the use of an additional abrasive operation after grinding. The first one requires a comparatively fine grind, which is completely removed and replaced by another surface pattern. The second requires a very rough grind which is altered, only, in pattern. The stock removal in either case will be a very few tenths of a thousandth.

In the first method, one of two processes is used to completely remove the ground pattern. They are sandpapering and superfinishing. Where the surface is to be sandpapered, it is essential that the grinding be of small ridge depth and that the lowest possible degree of waviness exist, because sanding has no capacity for geometrical improvement. If superfinish is to be employed, the grinding need not be so precise, because this process results in the almost complete removal of waviness. Either method will adequately remove fragmentation and annealing of surface.

Because it is impossible, by any known process, to absolutely remove waviness, either method should be controlled to produce new ridges just a little deeper than the remaining waviness. Then, as waviness is worn down, or an improved geometry has been generated by wear, scratches will still remain to distribute oil. This control is secured by variation in grit size of the abrasive, and by the length of time that it is applied. The pattern produced by either process will be essentially the same. It will be composed of alternate ridges and oil grooves parallel to each other.

In superfinishing, and sometimes in sandpapering, these ridge patterns cross each other to form a cross hatch. Too long an application of the abrasive should be avoided, as the grits become dulled, and burnish the surface, instead of cutting the uniform pattern desired to prevent incipient galling.

The second method of production of surface pattern starts with a rough grind of perhaps 100 or more profilometer reading. The additional operation removes the tips of the deep grinding ridges, reducing them to plateaus, all of which then are contained in the same cylindrical (or flat) plane. The surface will then be composed of some percentage of plateaus to act as the actual bearing area, and the balance of pits below that surface to serve as oil pockets. The greater the depth to which the tips are removed, the greater will be the percentage of true bearing area, or plateaus, and the smaller the percentage of oil pockets. The individual size of both plateaus and pockets is also determined by the degree of roughness or ridge spacing of the grinding. Where design permits the use of a lap, lapping can be used as the second abrasive process. Superfinishing is the only other method that can be used, and few restrictions by design will interfere. Sanding has not proved successful, because it produces a rounded plateau, tends to elongate the pits, and does not reduce the ridge tips to a uniform height.

Which of these two methods of oil groove production would give the best results, under various conditions,

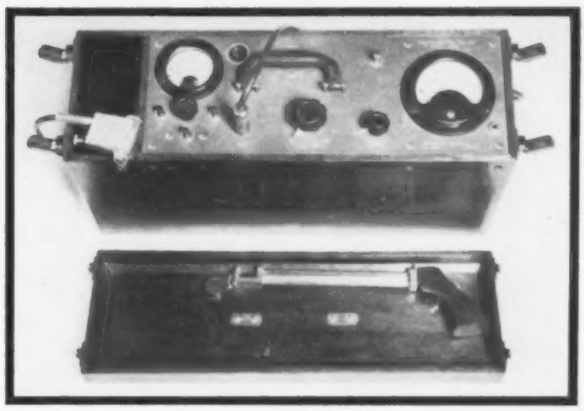


Figure 4 — The profilometer. The tracer head lies on the left hand lower corner of the amplifying unit. The measurement of surface roughness is read on the meter at the right.

is an unsettled question. It seems reasonable to believe that lubrication conditions, and the capacity to produce geometrical accuracy, could be the deciding factors. If the lubricant contained considerable grit, the surface with deep grinding pits, might result in less damage. The deeper pits would not only provide places for lodgment of grit, but allow a greater amount of wear before the complete disappearance of oil pockets. However, there might be a tendency to gall on the smooth areas, if they are too large or too completely smooth.

The first pattern, of evenly spaced minute ridges, should result in less damage by galling, if the waviness be little enough that smooth spots do not develop. It seems that the greatest protection is provided by the closest spacing of bearing area and oil supply, according to a recent report.

One of the few papers that have reported quantitative results regarding both scratch depth and surface pattern was given by Dayton, Nelson and Milligan, before the American Society of Mechanical Engineers. While their results apply only to their one set of conditions, they do show the kind of research that seems necessary, and the required attention to minute surface conditions.

Eleven different surface finishes were tested, produced by sandpapering, grinding, hyprolapping and loose abrasive lapping. The two metals were copper lead and 6150 steel of 42 Rockwell C hardness. The original finish varied from 10 down to 1½ microinches profilometer readings. Superfinish was not included in these tests.

Their results showed, decidedly, that the surfaces with low profilometer readings were much superior in capacity to carry load without galling and scoring. However, there was a considerable difference in the capacity of surfaces of approximately the same profilometer readings, but produced by different methods. Sandpapered was much better than loose abrasive lapped, for instance; and this must have been due to pattern.

My own analysis of this condition is based on micro-

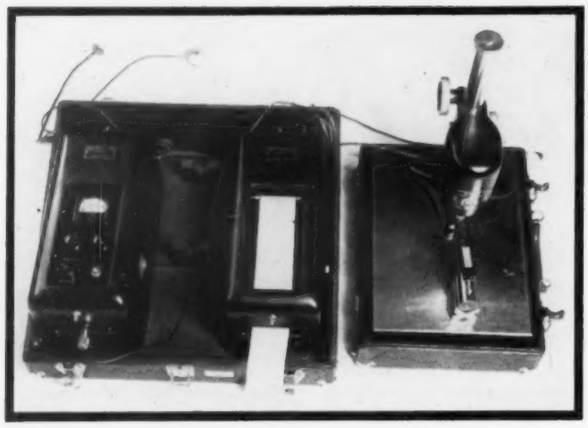


Figure 5 — The Brush surface analyzer. The surface being tested is on the vee-block on the surface plate. Its profile is drawn on the paper strip chart.

scopic examination of the two kinds of finish. A fine sanded surface is composed of exceedingly minute alternate ridges and valleys. They are quite regularly spaced, parallel to each other, and, in this case, lie in the same direction as the shaft rotation. A loose abrasive lapped surface has scratches arranged in random directions, with numerous comparatively large and very smooth areas between them. I believe that the inferiority of the lapped surface is due to the inability of the oil contained in one scratch to lubricate or contaminate the large area adjacent to it. It appears that the minute oil grooves must be very closely spaced, under their test conditions.

After determining that a sanded surface was most efficient of those tested, one sample was first corrected in geometry by lapping, then lightly sanded. This test showed "exceedingly high seizure resistance," the highest of any listed. As the bearing length was exceedingly short, only .150 inches, this forcibly demonstrates the results of improved geometry.

Wearing-in of the sanded-only samples for two hours resulted in an increase in capacity of nearly 34 per cent. Inspection with the profilometer and Brush analyzer did not show any change in the minute ridges; but a special technique, which allowed them to examine the ridge profile at 12500 diameters, showed a slight rounding or blunting of the tips. The authors were of the opinion that this blunting increased the area which actually carried the load, and thus was responsible for the increased capacity, after wearing-in.

If it is true, and I have long believed it is, that the shaft weight is carried on the tips of the surface irregularities (ridges in this case) the necessity for perfect geometry becomes obvious. Every ridge tip must be in such alignment that it carries its share of the load; and the more of them there are in a given dimension, the greater the load that can be carried, proving the necessity for surfaces of comparative smoothness. If we are to be successful in bearing improvement, such are the conditions that must be visualized. With this surface pattern, the unit of bearing dimension is not the inch, it is the single ridge.

The amount of clearance is also important, because the smaller it is the more nearly the planes of both the shaft and bearing will coincide, and thus increase the arc of contact.

Direction of ridge, and capillarity of surface, are other considerations which would bear investigation. A ridge parallel to the shaft rotation should wear longer, but will not be cross-wiped by lubrication. Some angularity, or cross-hatch pattern, seems indicated. Surfaces around 1 micro-inch or less hold a very thin oil film tenaciously, but any excess will collect in large globules. A small increase in roughness will again result in uniform distribution by capillarity. Under certain conditions, perhaps in combination with capillarity due to clearance dimension, assistance might thus be given to holding or spreading a film.

As mentioned before, the results obtained by Dayton, Nelson and Milligan apply only to their one set of conditions. Much remains to be done because of variations in bearing size, in metals employed, in lubricants and the methods of their application, in kind of bearing motion, and many other things. A sandpapered surface of 1½ micro-inches might not be the most efficient for another set of conditions at all, and it might not be the most easy to produce.

Nevertheless, certain well defined conditions are influential in the operation of every bearing. We can be sure that the minimum of waviness should exist; that fragmentation and annealing are detrimental; and that the actual bearing area (excluding grinding pits when employed as oil pockets) should have a low profilometer reading.

DISCUSSION

PRESENTED BY

H. H. WOOD, District Manager, Morgan Construction Company, Pittsburgh, Pennsylvania

H. H. SHAKELY, Master Mechanic Hot and Cold Strip Mills, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania

C. C. PECU, Lubrication Engineer, Bethlehem Steel Company, Lackawanna, New York

E. L. HEMINGWAY, Chief Metallurgist, Foster Division, International Machine Tool Corporation, Elkhart, Indiana

CHARLES PRITCHARD, Lubrication Engineer, Republic Steel Corporation, Cleveland, Ohio

C. R. HAND, Lubrication Engineer, Bethlehem Steel Company, Sparrows Point, Maryland

H. H. WOOD: I have no prepared discussion on this paper, but it has been carefully read with appreciation by members of our organization. If the subject matter is a little beyond the average bearing man, it still tends to make him open his mind to the why and wherefore of surface finish. Our company manufacturers a precision roll neck bearing and we have had experience with some of the points brought out in the paper. We try to

make our bearing as geometrically perfect as possible and obtain high surface finish. Results are good up to rated carrying capacity, but at times some of the difficulties that have been mentioned in the paper will show up. This means that there are still problems to be solved to the end that heavy duty precision bearings will give even better service in the future.

H. H. SHAKELY: Mr. Hemingway's splendid paper has brought out some very interesting points in the manufacture of babbitt bearings. Ideas beneficial to all of us especially those in maintenance work. We agree with Mr. Hemingway as regards finish of the shaft or journal which is to be operated in a bearing, and feel that with improved grinding methods we will be able to attain finishes that will be far superior to those at present.

As regards the surface of the bearing itself, we feel that in the case of bearings such as those used on the back-up rolls of the modern strip mills, spotting or relieving the pressure area by extremely light intermittent scraping has resulted in much longer life. However, much care must be exercised in removing this metal so that the load carrying capacity is not affected. Granting that manufacture of a bearing to the best known specifications is of prime importance, we still feel that bearing life greatly depends on the periodic inspection and maintenance of the surfaces as near to their original state as possible. This can be accomplished only by regular inspection and reconditioning. Entering oil wedges, bearing surfaces and grooves, must be maintained as the bearing wears.

In the case of sleeve type back-up bearings, wiping or galling is much more prevalent in bearings that have increased clearance due to either manufacture or wear. This, we feel, is due to two causes: first, if oil wedges as well as bearing surfaces are not carefully inspected as wear occurs, wiping will result, due to uneven distribution of the lubricant, and secondly, due to pounding, if the installation and operations are not carefully watched. Any bearing with clearance greater than normal, we feel, is safer if installed on the bottom back up where the weight of the roll holds it against the pressure area. If installed in the top, where the tendency is for the roll necks to leave the pressure area as the load leaves the mill and return with a hammer blow as the succeeding bar enters, very serious damage may result. This blow, being far in excess of the normal rolling pressure, breaks down the oil film and in time starts serious wiping or galling. Modern units are equipped with hydraulic roll balance systems to prevent such failures, but unless the system is in perfect condition, that is, where the work roll plungers hold the back-up roll tightly against the pressure area, some damage may result.

Our present bearings are not so designed to be used in either position, but, investigation is being made to determine if this is possible; then if wear occurs in the top unit it can be moved to a safer position on the bottom.

C. C. PECU: You spoke about galling. You spoke about wearing. But nothing has been said about pitting. We know pitting is caused by many things on ordinary gears, but what causes the pitting on the ring gear, nonferrous metal, in worm drives, with no extrusion of metal?

E. L. HEMINGWAY: In this particular case I wouldn't be surprised if it is one of two things: either corrosion or galling.

C. C. PECU: When you are speaking of galling, is there a dragging after the pit?

E. L. HEMINGWAY: Quite often.

C. C. PECU: This is not true in our case. Worm drive manufacturers would like to have somebody tell why a clear round circle, as it were, occurs there. You know, on a worm gear, one full tooth takes a major part of the load. Would you think it was caused by a hot spot and expansion of metal?

E. L. HEMINGWAY: It could be. That would be again a case of special form of fatigue, I would say, wouldn't you? I take that movement of metal due to expansion and contraction to be fatigue.

C. C. PECU: To show you how thoroughly we went in, if we have extrusion of metal where we show a large wear, then we would expect some flour of the nonferrous metal particles to be in the oil. We would also expect some of that to happen in any worm drive on account of the wear under extreme loading. We analyze the oil to find out what foreign matter is in it. We find a trace of steel, and we find a very small trace of nonferrous metal, but we can find large particles in the case, one side polished, and the other side rough.

E. L. HEMINGWAY: Did you ever try any extreme pressure lubricants of the corrosive type on that to break them in with?

C. C. PECU: I never dared do it, because I always wanted the man who furnishes the machine to take the load. I have been told many times that an extreme pressure lubricant could not possibly be used. I have used it in many instances with good results.

CHARLES PRITCHARD: This is a round-about way of coming back to the same thing, Mr. Pecu, but it is believed that a similar reaction takes place on back-up rolls, especially in the cold strip mill. That is where my experience in that particular field came from. In checking the final wear, you would find minute imperfections in the roll surface. The metal would tend to fatigue. Our thoughts in so far as the general reaction was concerned were based on the supposition that the oil was trapped in these imperfections, and it in turn, due to the hydrostatic head involved, would develop a metal fatigue, or working in the roll surface, and it would, under close examination, result in an opening with very sharp edges which would tend to grow in size. The only method we had to control this condition was to use a grinder and roll off those sharp edges which in turn would lessen the build-up. Of course it would mean that you would have to change a roll for normal causes but considerable tonnage could be added before it was necessary to do so. That may be an explanation as far as your worm gear unit is concerned, inasmuch as the high unit pressures encountered on a worm wheel would approximate the same general reaction in the presence of an oil as compared to the back-up roll.

I am convinced that pitting is caused by an overload on a small area which causes heat and the metal is expanded at that spot.

C. R. HAND: For the benefit of those present who are not familiar with the profilometer and Brush analyzer, I would like Mr. Hemingway to give us a short talk on how these instruments are constructed and used.

E. L. HEMINGWAY: Mr. Wood's statement that "the subject matter is a little beyond the average bearing man" leaves the writer somewhat perplexed. Perhaps the very unusual advantages we have had in examining hundreds of bearing surfaces, produced by so many sources, has given us an unsuspected degree of understanding of these conditions. However, it is not believed that many will find much difficulty in understanding the points brought out, even though they may be new to them. The writer is hopeful that readers will be awakened to the considerable possibilities that certainly exist for bearing improvement.

With reference to the difficulty of which Mr. Pecu speaks, I believe that Mr. Pritchard has essentially the right thought. Perhaps some small area of the surface projects very slightly above the mean area. Rubbing of this spot by the mating surface not only expands it by heating to a still greater height but weakens it through the generated heat and produces a stress around the edge of the involved area. If this stress further develops into a semi-circular crack, oil under considerable pressure could enter into that crack and tend to lift the area and eventually completely loosen a complete circle of fragmented metal. Even if hydraulic pressure had no effect, the alternate raising and lowering of the loosened area by heat would eventually result in fatigue break-up.

Mr. Shakely's description of his experience with back-up rolls is interesting, indeed. The advantages of correct clearance and of proper means to distribute the lubricant are clearly demonstrated by his remarks.

As he has so clearly pointed out, the minimum permissible clearance has several good features. It results in a greater arc of contact, with consequently increased load capacity; better retention of oil over all of the surface, by capillarity; better accuracy in the rotative position; little or no chatter and pounding; and less trouble from wear, etc. Of course, the better the surface finish and the better the geometrical shape of the bearing, the more the clearance can be reduced.

Another very good point Mr. Shakely has made is his comment on the influence wear has upon the action of oil grooving or wedges. An oil groove with sharp edges has little value; it shears off the oil instead of allowing it to pass out upon the bearing surface. One that has originally been properly beveled may wear to have sharp edges, and bearings should regularly be inspected for correction of such a condition.

The profilometer is composed of two units, the tracer head and the amplifying unit. The tracer head is about the size of a package of cigarettes. From it projects a minute shaft carrying a very small pointed diamond which contacts the surface being tested. The tracer head slides over that surface on a pair of rounded buttons while the diamond point and its spring mounted shaft move up and down over the surface inequalities. On the upper end of the moving shaft is a tiny coil which moves within the field of a permanent magnet inside the tracer head. Such movement of the coil cuts lines of force and creates a minute current of electricity which is proportional to the depth of the surface scratches. This current is lead into the amplifying unit where it is increased by several thermionic tubes to a quantity measurable by a rugged meter. As the current varies according to the depth of surface roughness, the meter is calibrated to read in millionths of an inch instead of millivolts.

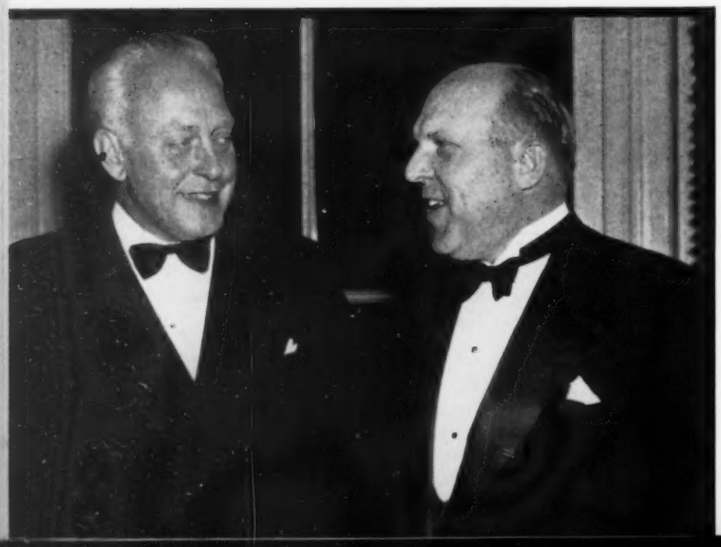
The instrument shows the running average of the scratch depth by the root-mean-square method. This means that the meter reading must be multiplied by a figure of 3 to 5 to get the actual peak to valley height.

The Brush surface analyzer has the same sort of diamond point and rounded button for the head to ride upon. However, the current is caused by the bending of a Piezo crystal by the movement of the diamond. This crystal has the property of creating a current which is proportional to the degree of flexure. The running average is not shown in this case; instead a curve is drawn on a moving paper chart which represents the actual magnified shape of the surface profile.

It does not appear that the actual dimensions indicated by either instrument are completely accurate. They will repeat exactly alike on the same surface, and do adequately compare the qualities of two surfaces.

Equipment Manufacturer Acquires New Quarters

R. J. Wean (right), president of the Wean Engineering Company, shown here with J. H. Kindelberger, president of North American Aviation.



▲ THE Wean Engineering Company, Inc., Warren, Ohio, has moved from the offices in Second National Bank Building, which it has occupied since the incorporation of the company in 1929, to its recently purchased property at 347 North Park. The move, according to R. J. Wean, president of the company, was due to expansion necessary under the national defense program.

Mr. Wean stated that a technical training program is contemplated for the general benefit of industrial companies in that district, and would require an entire floor of the new headquarters.

The Wean Engineering Company specializes in the manufacture of sheet, tin and strip mill machinery, and in addition to this is doing a large amount of special machinery work for the war effort.

RELATION OF *Flame Character* TO *Open Hearth* OPERATION

. . . . . the fuel department at Bethlehem's Maryland plant has developed equipment and methods for taking relative radiation readings of open hearth flames . . . . . tests have shown a definite relation between these readings and the production rate of the furnace . . . . .

by A. J. Fisher

FUEL ENGINEER

BETHLEHEM STEEL COMPANY

SPARROWS POINT, MARYLAND

▲ OPEN hearth operators have always been conscious of the difficulty of analyzing the tonnage performance of their furnaces, for comparative purposes. They have all seen, sometime or other, exceedingly fast furnaces, without being able to explain why they were fast or exceedingly slow furnaces, without knowing why they were slow. The lack of analytical understanding in these cases is very disconcerting, and is a drawback in the development of ways and means for designing and building fast working furnaces.

According to the Buell index (Factors of Open Hearth Design and Practice, A. I. S. E. Yearbook, 1941, p. 132), the production of an open hearth furnace is related to four items as follows:

Item 1 — The furnace and its auxiliaries . . . 30 per cent
Item 2 — The plant . . . . . 10 per cent
Item 3 — The raw materials . . . . . 20 per cent
Item 4 — The personnel . . . . . 40 per cent

The fact that these four items have always been more or less inter-related, makes their separation difficult. The purpose of this paper is to show ways and means to analyze, separate, and evaluate the furnace and its auxiliaries, item No. 1 of the Buell index. Although this paper is primarily written with liquid fuels in mind, it is hoped that it will also prove of some value to users of gaseous fuel.

Presented before A. I. S. E. ANNUAL CONVENTION, Pittsburgh, Pa., Sept. 22-24, 1942

The fuel department at the Sparrows Point plant has devoted much time and effort to find and develop a method whereby the radiating power of an open hearth flame can be observed and recorded. We have read and studied works already completed on the measurement of flames of high intensity and the factors governing their radiation of energy. As a result of this work, and after much trying and observing, we have developed equipment and methods of taking relative radiation readings of open hearth flames, and have shown a relation of these flame radiations to the tonnage of steel produced per hour per furnace. The results so far have been most encouraging, and should ultimately lead, we believe, to a complete understanding of this complex problem.

The fact that we have been able to divorce the furnace item from the plant, raw materials, and personnel items has been due, in great part, to the regular and consistent operation of our furnaces. For the past eight years these oil fired furnaces, 26 in all, have all been equipped with complete automatic control of fuel, reverse, furnace pressure, heat potential, etc., and a stabilized operation of these instruments and controls had been reached before the study of flame analysis was started.

Figure 1 shows a typical schedule card indicating the desired flows, pressures, and temperatures of the various fuel items on the furnace, at the different stages of the heat. Each item is scheduled and is maintained at the desired point by automatic regulators and controls.

Open Hearth Furnace No. 79

	Melt	Ore	Lime	Working
Oil flow	500 max.	500 max.	400 max.	450 max.
Air flow	14,500	14,500	14,500	14,500
Steam pressure—oil on	110 max.	110 max.	80 max.	90 max.
Steam pressure—oil off	15	15	15	15
Furnace pressure	105	105	90	90
Oil temperature	225	225	175	175

Date: August 1, 1942

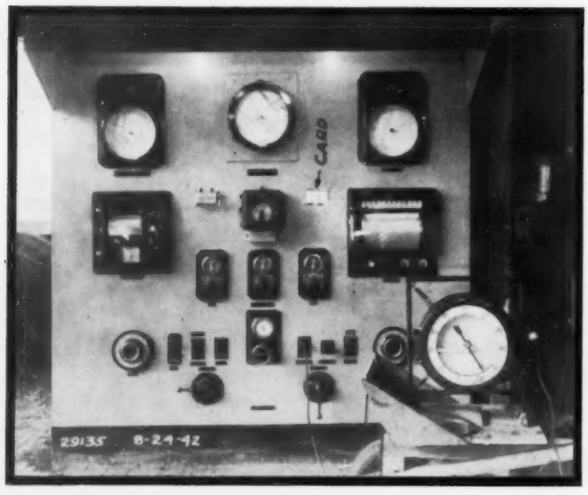
JOHN DOE
Superintendent

Figure 1 — Typical schedule card giving desired flows, pressures and temperatures of the various fuel items for different stages of the heat.

Note the position of the card in its frame on the gauge board shown in Figure 2. These cards are typewritten, signed by the superintendent, and placed on the boards at the beginning of each month. As the age of the furnace increases, etc., changes are made on the schedule card in pencil by the superintendent, during the month.

The greatest part of the heat transfer from the flame to the bath is by radiation, and because of refractory limitations, the flame must be placed close to the bath so that the major part of this heat will radiate directly from the flame to the bath. The amount of heat transferred follows the Stefan-Boltzman radiation law. This law, as applied to flames, is as follows:

Figure 2 — The schedule card of Figure 1 is mounted on the instrument board for each furnace. The potentiometer for reading flame radiation is shown in the foregound.



$$\text{Btu per hour} = C\,A\left[\left(\frac{T_f}{100}\right)^4 - \left(\frac{T_s}{100}\right)^4\right] x\, e_f\, x\, e_s$$

C = radiation constant 0.174
A = area in sq ft of radiating or irradiating surface, whichever one is smaller. Usually the area of the flame.
T_f = absolute temperature of the flame, (460+temperature above zero, F).
T_s = absolute temperature of the slag (460+temperature above zero, F).
e_f = emissivity of the flame envelope.
e_s = emissivity of the slag.
For black bodies e_f and $e_s = 1.0$

Radiant heat travels at the rate of 186,000 miles per second. The speed of travel of the flame is therefore relatively unimportant. The important points are, that it should have the proper area of radiating surface, high temperature, and high emissivity.

COMPONENT ITEMS OF FLAME RADIATION

The study of flames, in open hearth furnaces, resolves itself into: (a) shape of the flame; (b) position of flame in the furnace; and, (c) heat radiation per square foot of flame to the bath.

A. The shape of the flame is a function of the burner characteristics and is a simple dimensional problem. The flame may be long and narrow or short and bushy according to the size and shape of the burner nozzle, and the pressure and temperature of the fuel and atomizing medium.

B. The position of the flame in the furnace is also a dimensional problem. It is a compromise between a good position for melting scrap and a good position over the molten bath. With a little care in charging scrap, to prevent the scrap from piling up too high directly in front of the burner, the burner can be set in a fixed permanent position in relation to the bath. Inasmuch as the position of the flame, in relation to the bath, is

very important and critical, the burner should be carefully located after each rebuild and again, if necessary, after the furnace is expanded and brought to operating temperature. It should then be fixed permanently until the next rebuild.

C. The radiation to the bath per square foot of flame surface is considerably more complex, because many more components are involved. These are as follows:

1. *Carbon content and temperature of the fuel* — High carbon fuels have a greater potential for producing luminosity. The luminous or incandescent carbon particles increase the emissivity, that is, the radiating power of the flame envelope. The luminosity-producing carbon contained in the common fuels is as follows:

Fuel	Lb of free carbon plus combined carbon, excluding $CO+CO_2$, per million Btu
(a) Topped tar or pitch	58.2
(b) Tar	55.6
(c) Bunker C fuel oil	44.5
(d) Natural gas	31.8
(e) Coke oven gas	20.3
(f) Producer gas (washed)	7.02

High-temperature liquid fuels of low viscosity mix better with the atomizing agent and give a more uniform quality of flame than do low-temperature fuels.

2.*The kind, amount, and temperature of the atomizing agent* — These factors all have a bearing on the thermal decomposition of the fuel, in respect to time. The common atomizing agents are steam, air, and blast furnace gas. This will be discussed in more detail later.

3. *The degree of mixing fuel and atomizing agent* — Good mixing is very important, as it produces a uniform flame. It is governed by the mechanical relations between the mixer used and the temperature of the fuel and the atomizing agent.

4. *Preheated air temperature* — High temperature air is very important in developing high flame temperatures. Hot air not only produces an initially hot flame, but it also prevents the inlet end of the furnace from getting too cold and from absorbing a large amount of the flame radiation.

If the regenerators are large and ample, giving preheated air temperatures of 2000 to 2200 F, it is desirable to set the air flow on a furnace at a constant figure throughout the heat. When the refractories reach the burning point, the fuel can be reduced, leaving the excess air available for cooling and stabilizing the furnace. This procedure makes possible maximum fuel flow and saves time on the heat. If the preheated air is above 2200 F, as is the case with large newly rebuilt regenerators, the air flow should be kept constant and increased above the normal amount ordinarily used. This excess air will have a cooling action and will enable the furnace operator to carry the normal fuel flow without a corresponding loss in tonnage. If, however, the temperature of the preheated air is below 2000 F, a loss in tonnage is sure to occur. On furnaces with low-temperature air, it is possible to ratio the air and the fuel without getting into too much difficulty with refractory burning. The importance of air temperature and its relation to flame radiation will be discussed again later on in the paper.

5. *Design of the port end* — The port end construction must mix the air and the fuel so that a protracted flame of correct length can be maintained. Too intimate a mixture will lower the luminosity, decrease the flame radiation at the first and second doors nearest the burner, and consequently increase the available heat at the third, fourth, and fifth doors. In such a furnace the refractories will burn at the out-going end.

The port ends and burner position of every furnace should be checked with transits or levels after rebuilding, in order to insure proper duplication of dimensions and furnace practice.

6. *Burner nozzle* — The burner nozzle should be kept clean at all times. Dirty burners diffuse the flame and cause premixing or burning of the fuel without luminosity. This will be taken up later.

7. *Port slopes* — Port slopes from the bath to the burner should be kept low in order not to interfere with the flame. Any distortion of the flame will have the same effect as a dirty burner, increasing premixing and lowering flame radiation.

8. *Furnace radiation loss* — The temperature of the surrounding brickwork has a very important bearing on flame radiation. For each size of furnace there is a balance between refractories and insulation where maximum tonnage can be made. If the furnace is overinsulated, the fuel will have to be reduced, and since the bath is heated primarily from the flame, tonnage will be lost. If on the other hand, insulation is left off and the refractories wear thin, the tonnage rate can be maintained only by increased fuel consumption. Once the proper fuel rate is established and the correct amount of refractories and insulation is found by trial and error for a new furnace, the tonnage rate on the furnace may be maintained by gradually increasing the fuel rate as the refractories wear thin.

It is almost impossible to separate and evaluate the exact relation of the items set forth in A, B, and C. However, it is possible to analyze and record the total effect of all these items. This effect is called the flame radiation factor and represents the relative maximum radiation from a flame at the position taken in the furnace. A study of this radiation effect will eventually lead to a better understanding of each of its components, and the magnitude of their influence on the combined radiation from the flame.

FLAME RADIATION INSTRUMENT

The equipment used for taking and recording flame radiation factors is composed of two units. Figure 2 shows the indicating-recording round-chart potentiometer. This instrument is hung by springs in a steel frame and is mounted on a rubber-tired wheelbarrow. It is plugged into the electrical service recepticle on the gauge board at each furnace. A large indicating dial is desirable because the observer taking the reading keeps his eye on the instrument in order to coordinate the speed of travel of the radiation tube through the flame and the speed of change of the instrument position. The emissivity dial on the instrument is set so that the 100-reading on the chart corresponds to 21 millivolts from the radiation tube. This is an arbitrary scale chosen to represent the highest flame radiation values so far recorded. Since establishing the scale we have found flames that were above 21 millivolts and conse-

quently over the 100 reading, but these were exceptional cases, few and far between, and did not warrant starting a new scale.

For a permanent installation this instrument should be a high speed strip-chart machine permanently located, one to each shop with recepticles for plugging in the radiation tube at each furnace. The instrument should have a fast-running chart of 60 in. per hour, and have a zero scale cut-out to stop the chart drive when no readings are being taken.

Figure 3 — Flame radiation readings are taken by placing the radiation tube at the wicket hole in the furnace door.

Figure 3 shows an observer placing the radiation tube at the wicket hole of an open hearth furnace. The tube has a long handle and a special frame for spacing and centering it at the wicket hole. A conventional radiation tube is used with a special mica screen. With this arrangement, wave lengths between 0.2 and 5 microns are absorbed, which is practically all the radiation emitted by a heat source in the temperature range of 3200 F. The observer, after having placed the tube in position at the lower edge of the flame, turns around facing the instrument and slowly depresses the radiation tube handle, thus causing the tube to pass through the flame from the bottom to the top.

The flame is observed at the first and second doors nearest the burner, after the lime boil and prior to tapping and alloy additions. This is when the bath is quiet and the furnace atmosphere clear. Very few metallurgical gases are given off at this time and an unobstructed view of the flame may be had. Considerable skill and experience are required on the part of the observer, in order to take the readings when the furnace is clear. If the furnace is not clear, the reading will be low and therefore not comparable.

The flame readings are taken on the first and second door, because any heat not transmitted in this part of the furnace will be carried over to the third, fourth, and fifth doors and cause the furnace to burn in the ports and uptakes of the outgoing end, or suffer a loss in tonnage by a necessary curtailment in the amount of fuel used per hour. The problem is, therefore, to create a flame that will heat both the ingoing and outgoing ends of the furnace to the burning point at the same time. Such a flame would of necessity have to be above a 100 flame-radiation reading on the first and second doors. This would be higher than the maximum standard set up in this paper, and would from present observations, be almost impossible to achieve, except on furnaces with large newly-laid checkers.

From this analysis it is readily seen that the working efficiency of an open hearth furnace is entirely dependent on the amount of heat extracted from the flame at the first and second doors. All of the reactions between the oil, steam, and air cannot be completed at these two doors. The only way to extract maximum heat from the flame at this point is by partial burning of the oil and the air on the outside of the flame envelope, and by cracking the mixture of oil and steam on the inside. This will give a flame of high luminosity due to the free carbon particles produced in the flame, thus increasing the black-body properties. As the radiating power of a flame is a function of its temperature and emissivity, any addition in flame luminosity will materially increase the radiation exchange between flame and bath.

For accurate, comparable flame-radiation readings, the oil, steam, air, and furnace pressure should all be set at some common standard value for at least one hour before the readings are taken. Otherwise the temperature of the furnace may not be at equilibrium with the fuel input, and distorted readings will result.

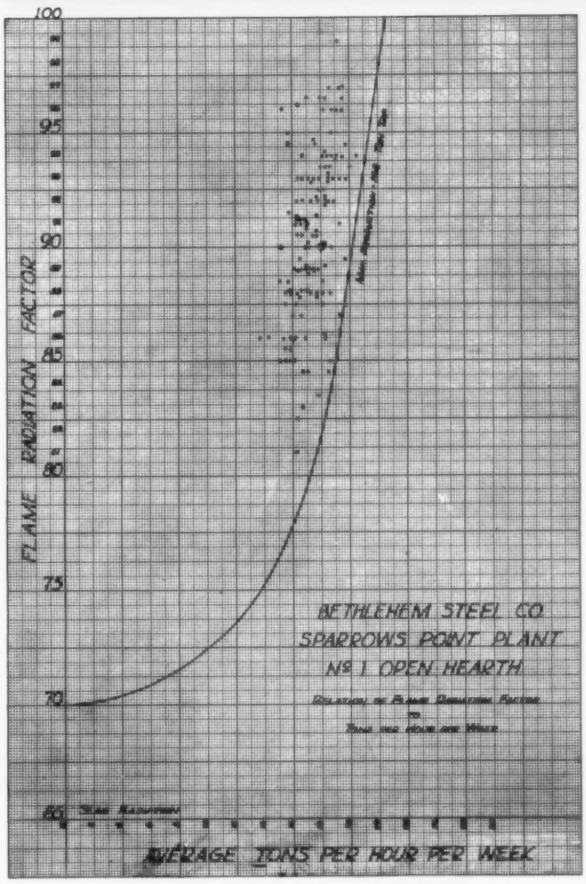
RELATION OF FLAME RADIATION TO TONNAGE

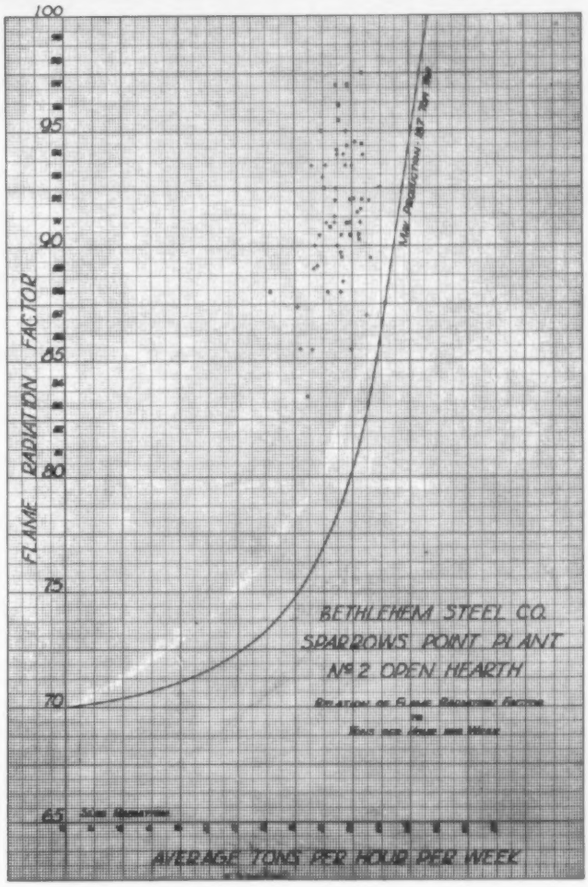
The first flame radiation readings were taken to show what relation, if any, existed between flame radiation and the tons of steel produced per hour. These observations are shown on Figures 4, 5, and 6 for our No. 1, 2, and 3 open hearth furnaces, respectively. Each point represents the average reading taken on the first and second doors nearest the burning end of the furnace, plotted against the average weekly tonnage. The charts show a definite relation between flame-radiation readings and tonnage. The wide distribution of the points on these charts to the left of the line of maximum production indicates the influence of the last three items of the Buell index — the plant, the raw materials, and the personnel.

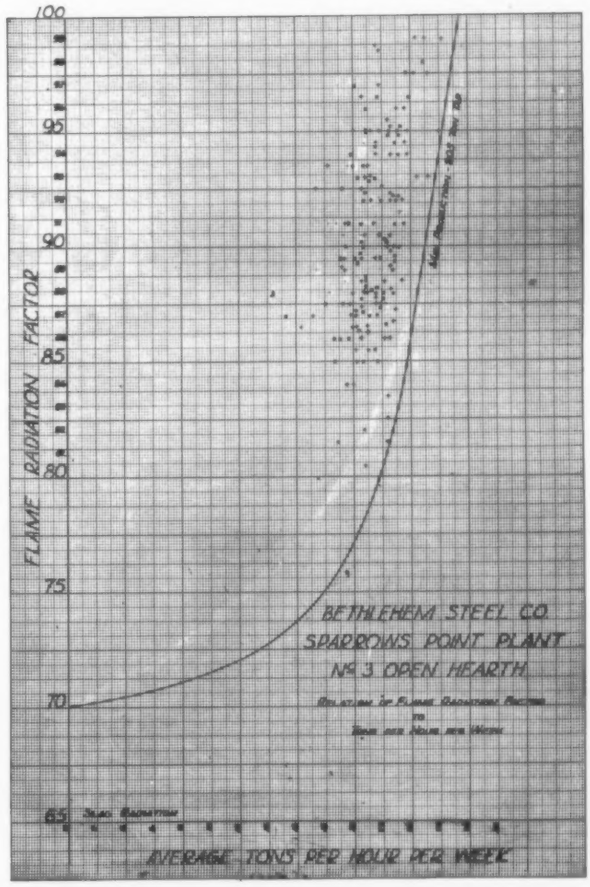
Most of the readings below 90 were taken in the summer, whereas nearly all of those above 90 were taken in the winter time. This proves that the dryer air during the winter months produces the higher flame radiation readings.

The wide distribution of the points between 80 and 100 flame readings is due in great part to dirty burners, high slopes under the flame, erratic mixing of oil and steam, and to failure to carry the proper volume of oil to compensate for the humidity in the air and the age of the furnace.

Although it is possible to produce furnaces operating







Figures 4, 5 and 6 — Flame radiation readings for three open hearth furnaces plotted against weekly averages of tons per hour.

at 100 flame radiation readings, it is not practical to operate these furnaces at such a high reading without complete automatic control and strict fuel scheduling. This is necessary in order to prevent excessive refractory wear on the furnace, which would cancel the gain in tonnage by the higher flame radiation readings, because of increased refractory maintenance.

The ideal furnace would be one with stabilized flame conditions and with a fuel input automatically regulated by the heat potential in the furnace. It is surprising how much fuel can be maintained and burned in a furnace without damage to the refractories, provided the amount is reduced for short intervals during the heat when refractory burning would otherwise occur. The fact that most first helpers cannot regulate their furnaces to close temperature tolerances, and the fact that the furnace heat potential at 3100 F cannot be measured and sustained accurately, are responsible for a substantial reduction in tonnage in most open hearth operations today.

Figure 7 shows the relative maximum production lines for furnaces tapping 75, 100, 125, 175, and 200 tons, respectively. These lines are calculated and drawn from Figures 4, 5, and 6. The incremental increase in tonnage for a 200 ton tap furnace from an 85 to a 100

flame radiation reading is 3.6 tons per hour per week, or 15.4 per cent. However, inasmuch as these analyses are all the result of average shop conditions, it seems certain that the incremental increase on any individual furnace from 85 to 100 flame radiation factor may be as much as 25 per cent.

The average slag radiation reading prior to tapping is 65, as indicated on the charts. It is thought that a 70 flame reading would be the point of zero production on all furnaces, as it would be impossible to get the metal hot enough for tapping before it went out through the bottom or sides of the furnace.

In the case where the flame is sighted with the radiation tube, the millivoltage produced can be written as follows:

$$\text{Emf output} = C\ e_f\ (T_f^4 - T_i^4), \text{ where}$$

C = instrument constant
e_f = emissivity of the flame
T_f = absolute flame temperature
T_i = absolute instrument temperature

Similarly the millivoltage produced when sighting the slag is as follows:

$$\text{Emf output} = C\ e_s\ (T_s^4 - T_i^4), \text{ where}$$

C = instrument constant
e_s = emissivity of the slag
T_s = absolute slag temperature
T_i = absolute instrument temperature

Therefore the radiation exchange between the flame and the slag may be written as follows:

$$\text{Radiation exchange} = [C\ e_f\ (T_f^4 - T_i^4)] - [C\ e_s\ (T_s^4 - T_i^4)]$$

Inasmuch as T_i^4, the absolute temperature of the instrument, can be entirely neglected due to its insignificance, the equation becomes:

$$\text{Radiation exchange} = C\ (e_f\ T_f^4 - e_s\ T_s^4)$$

The radiation exchange between the flame and the slag, for various flame radiation readings will be as follows:

(1) Flame reading	(2) Slag reading	(3) Radiation exchange	(4) Per cent efficiency
100	65	35	100
95	65	30	85
90	65	25	71
85	65	20	57
80	65	15	43

The amount of heat transmitted to the bath by a flame with an 80 reading is, therefore, only 43 per cent of that transmitted by a flame with a 100 reading.

THE SHAPE OF THE FLAME

The shape of the flame should be adjusted to the size and shape of the furnace. The area and shape of the burner nozzle and the pressure of the oil and steam are most important, as these factors determine the angle of the conical flame.

Figure 8 shows a conventional open hearth burner with its tip set back ¼ in. in the cooler. The tip is clean

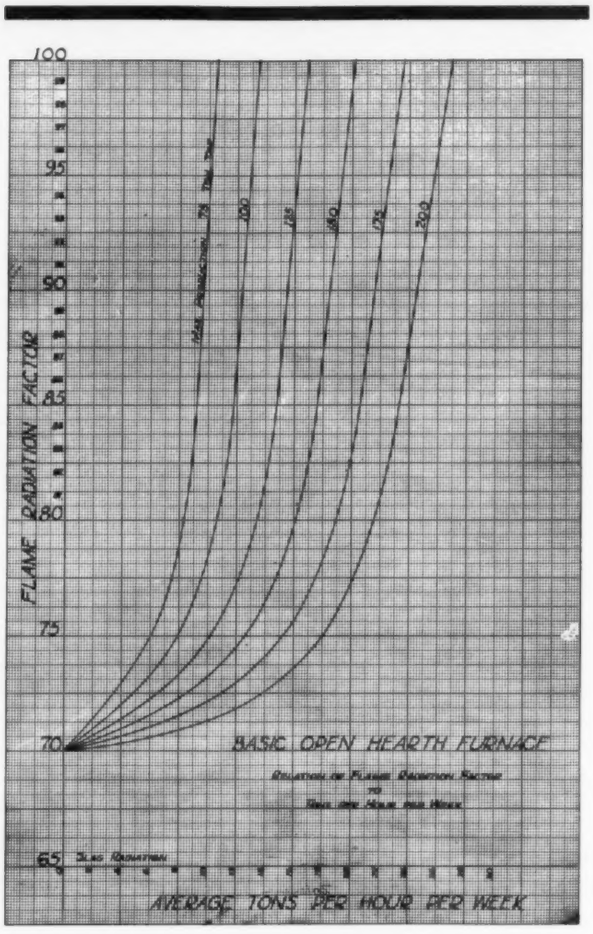


Figure 7 — Chart showing flame radiation values vs weekly average of tons per hour for furnaces of various size.

and has a very small conical angle. This gives a flame that is both small in total area and low in flame radiation at the first door, as indicated by the charts in this figure. Figure 9 shows the same tip after it has become dirty. In this case the conical angle is too wide. The flame envelope is rough and irregular, which causes premixing and non-luminous combustion. This gives a flame with low radiation factors at the first door, as indicated by the charts. Figure 10 shows the same conventional tip set back 1 in. from the face of the cooler. The back-drafting effect of the tip in the cooler causes the flame angle to widen. This increases the flame radiation factors at the first door to about the same as those on the second door, and produces a very good flame, as shown by the charts. However, this burner will eventually become dirty at the cooler face and the flame envelope will become irregular, producing premixing, which lowers the flame radiation on the first door, as shown by the charts in Figure 11.

In order to eliminate the dead-end steam and to produce a burner that would not accumulate carbon at the tip, a burner as shown in Figure 12 was tried. Although the dead-end steam was eliminated by this arrangement, it was not possible to overcome completely

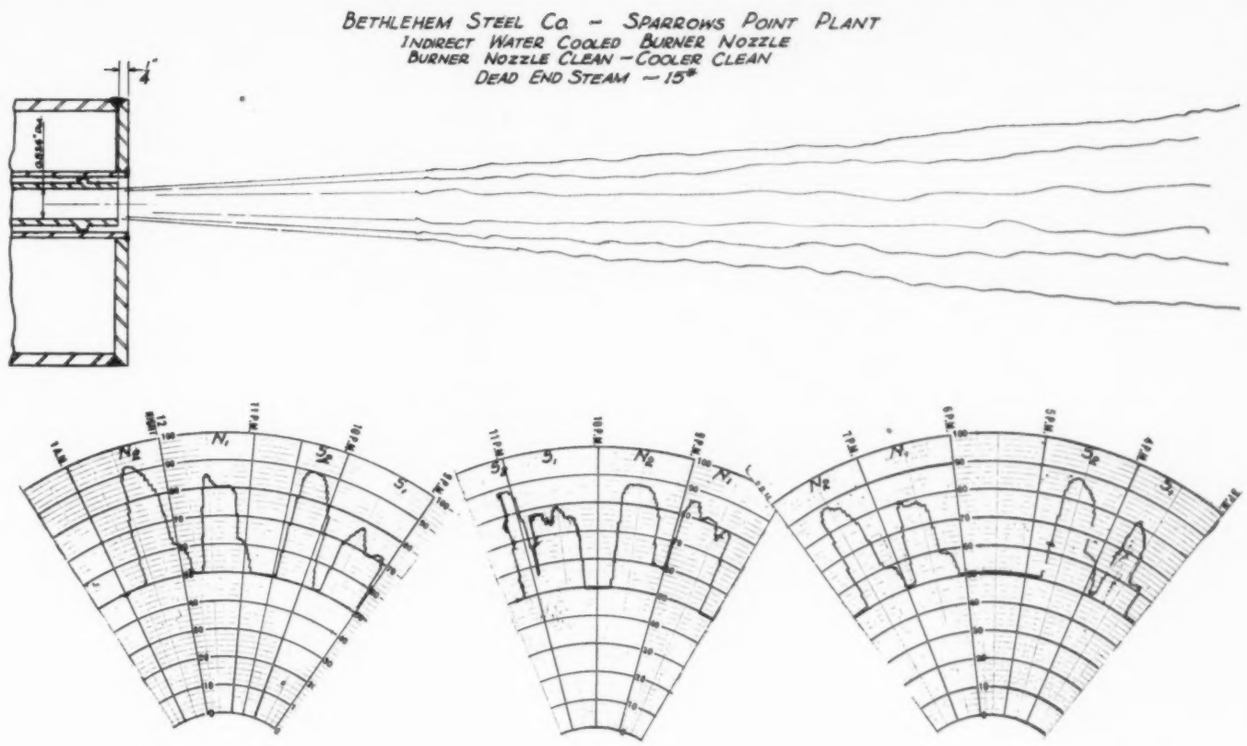

BETHLEHEM STEEL CO. - SPARROWS POINT PLANT
INDIRECT WATER COOLED BURNER NOZZLE
BURNER NOZZLE CLEAN - COOLER CLEAN
DEAD END STEAM - 15#

Figure 8 — (above) Flame radiation readings for conventional open hearth burner with tip set back ¼ in. in the cooler.

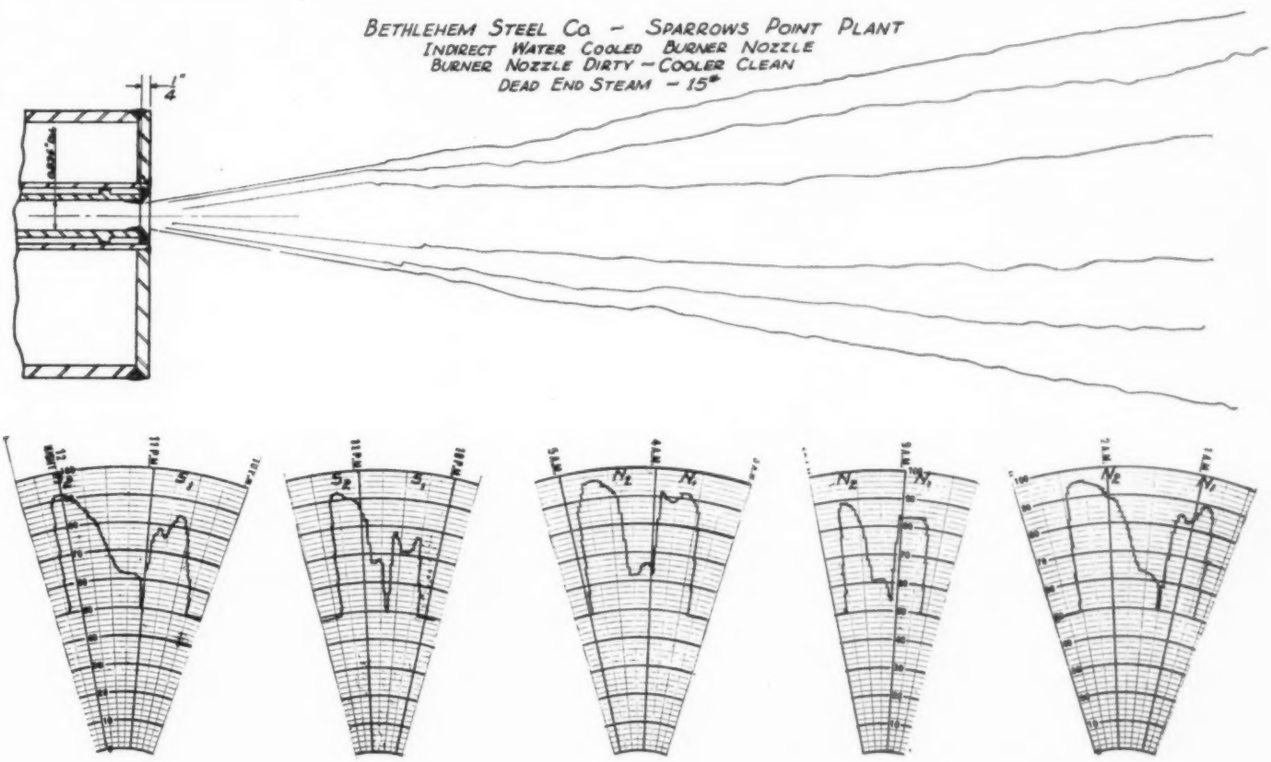

BETHLEHEM STEEL CO. - SPARROWS POINT PLANT
INDIRECT WATER COOLED BURNER NOZZLE
BURNER NOZZLE DIRTY - COOLER CLEAN
DEAD END STEAM - 15#

Figure 9 — (below) A dirty burner tip gives an irregular flame, with low radiation factors at the first door.

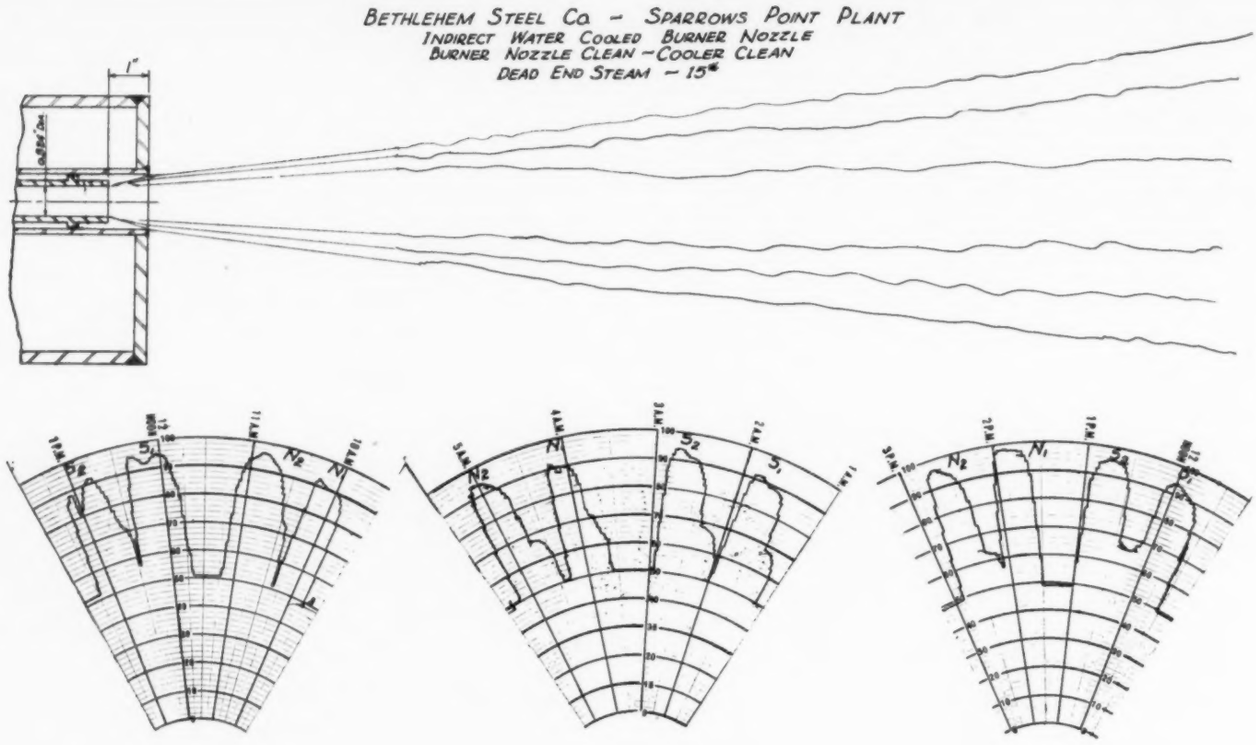


Figure 10 — (above) Setting the burner tip back 1 in. in the cooler widens the flame angle and increases the radiation factor at the first door.

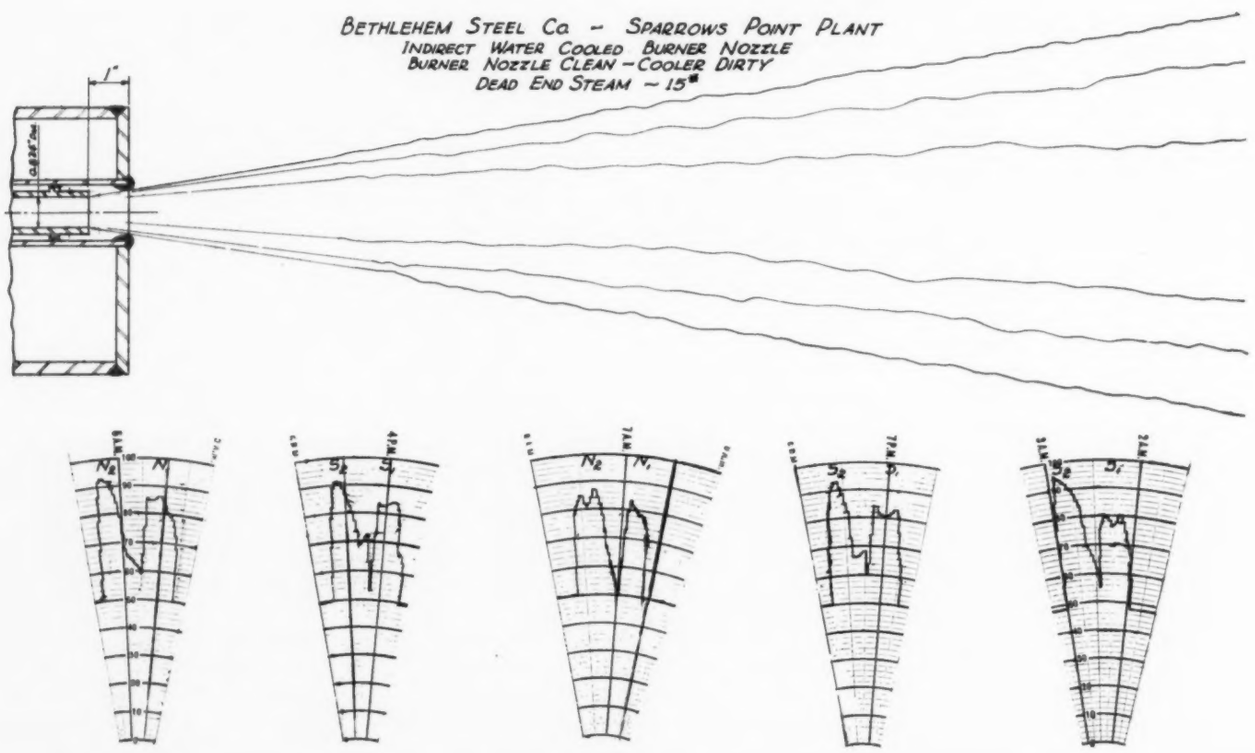


Figure 11 — (below) When the burner tip of Figure 10 becomes dirty, the flame also becomes irregular, with lowered radiation factor.

the carbon trouble, principally on account of minute leaks at the oil shut-off valve. The frequency of cleanings were, however, materially reduced.

The burner tip produced a flame with too small average conical angle which decreased the area of the flame envelope. In addition the flame radiation readings were low at the first door, as may be seen from the charts. The refractory erosion at the outgoing end of the furnace was excessive due to the lack of sufficient radiation at the first door.

When burners become dirty, the nozzle area is usually reduced. Since the flow of steam is controlled by pressure, any restriction in the burner will decrease the amount of steam. The resultant effect is a lowering of the flame radiation at the first and second doors. This lowering of the flame radiation of a dirty burner is therefore due to two factors: (1) the reduction in the amount of steam used per gallon of oil; and, (2) the increased premixing of the flame envelope and the air stream which lowers the luminosity of the flame. For the effect on flame radiation caused by a decrease in the amount of steam used per gallon of oil, see the values in Table I, which give the peak reading taken from the potentiometer charts.

THE POSITION OF THE FLAME IN THE FURNACE

The position of the flame in the furnace is of prime importance. By observing the manner in which different furnaces operate with respect to tonnage, together with the flame radiation readings at the first and second doors, we have by the trial and error method, arrived at a good flame position in the furnace. This position is shown in Figures 13 and 14. Three critical positions of the flame in the furnace have been observed.

Position A — The lower part of the flame should strike the bath opposite or ahead of the center line of the first door.

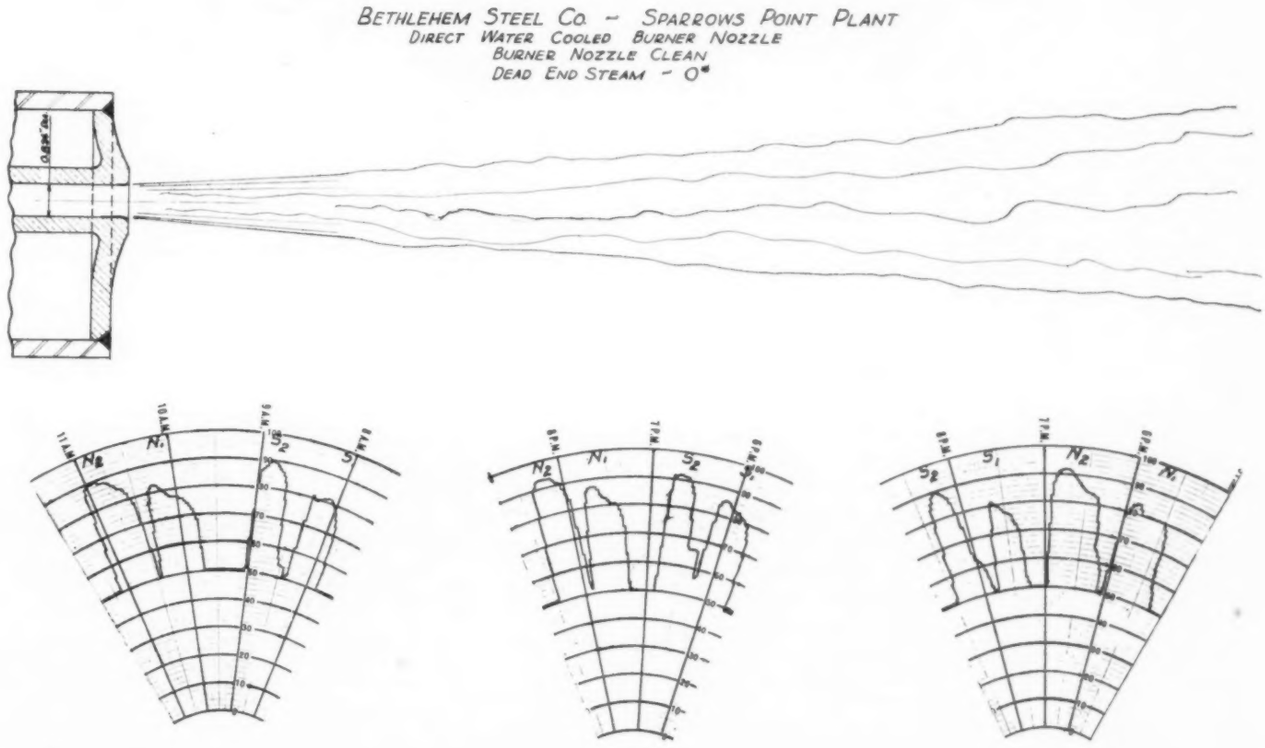
Position B — The top of the flame should be tangent to the line of sight from the wicket hole of the seconp door to the skew back line of the furnace.

Position C — The flame should be transparent at the third door wicket hole, so that the refractory outlines on the back wall are visible through the flame.

Not all open hearth furnaces can be judged from this standard, inasmuch as the port-end construction varies too much. Furnaces with short end construction should have flames with wide conical angles, and their flames may have to be located somewhat differently from those shown in Figures 13 and 14.

Furnaces with long slopes between the bath and the burner frequently built up these slopes during normal operation. This interferes with the flame, causing it to drag down the slope, thereby increasing premixing and lowering the flame radiation at the first door. The slopes should always be kept well below the flame to prevent interference with its protraction and luminosity.

Figure 12 — This burner tip arrangement reduced the frequency of cleaning, but gave a reduced flame envelope area, with low radiation factors.



FLAME RADIATION — INDIVIDUAL FURNACES

The normal flame-radiation practice of the twenty-six furnaces in our plant is given in Table I. An examination of the readings on the first and second doors, under normal operating conditions, shows a substantial variation for individual furnaces, indicating a loss in efficiency in many instances. The readings may be classified as follows:

	(1) First class (92-89 min.)	(2) Second class (89-86 min.)	(3) Third class (86-83 min.)	(4) Fourth class (83-80 min.)
	58	62	63	60
	59	66	64	61
	75	68	67	65
	82	71	69	73
		87	72	83
			74	84
			79	86
			80	
			81	
			85	
Number of readings	4	5	10	7
Per cent of total	15.4	19.2	38.5	26.9

The grouping of the furnaces above was arrived at by using the indicated flame readings as a minimum; discarding the lowest reading taken in most cases.

No. 82 is the outstanding furnace in this comparison, its first door flame radiation is higher than the second door, and for 100 lb of steam it has a first door flame radiation reading of 100 for both the north and south burners. The reduction in steam pressure from 100 to 80 did not materially affect the readings and the reduction from 80 to 60 still showed flame readings above 90. After closely observing furnaces like 82 one gets a pretty good idea of the physical nature of the various items contributing to high flame-radiation factors. No. 61 furnace shows very high flame-radiation readings at the north end and very low at the south end. By a process of elimination, the difficulty at the south end of this furnace could readily be found.

No. 65 furnace shows the poorest flame-radiation readings. Those for 100 lb of steam are fair but the first door falls off materially for 80 and 60 lb of steam.

Although 60 lb of steam is rarely used in normal practice, readings taken at this pressure are valuable, as they indicate weakness that would not be otherwise shown.

Although the above tabulation of furnace standing does not indicate a good furnace performance, it must be born in mind that these comparisons are new and that the furnaces studied have tonnage rates that may be considered above average for the industry as a whole. The study does show, however, that there is still room for improvement; and it points out, in a tangible manner, the direction in which improvements should be made.

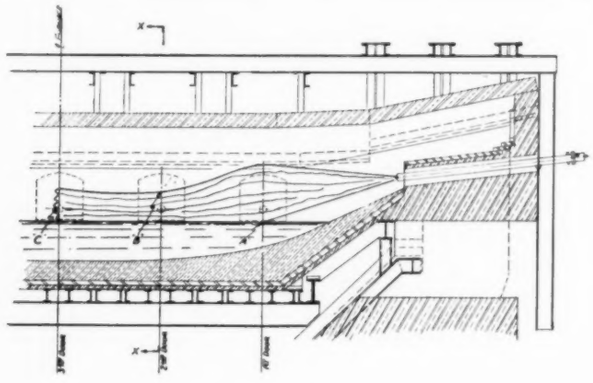
RELATION OF FLAME RADIATION — PREHEATED AIR

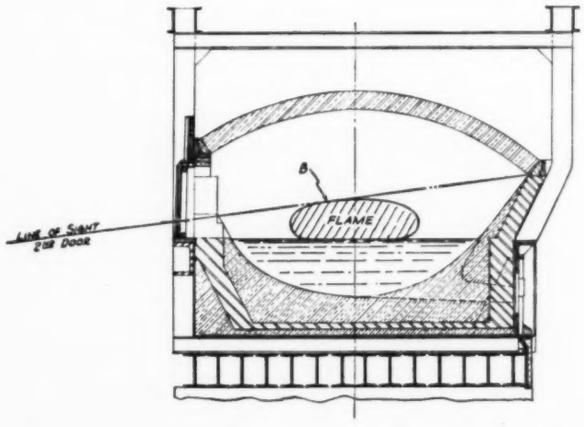
The one single item that has the greatest effect on flame radiation at the first and second doors of the furnace is the temperature of the preheated air.

Table II shows a series of readings taken on the first heat of seven furnaces after their rebuild, or quick roof. It is readily noted that extremely low radiation readings were recorded even when high fuel rates were used. This accounts for the unusually long time of first heats, which normally take 11 to 20 hours from charge to tap. The relation of flame-radiation readings, low air temperature, and long time of heats are clearly shown by this tabulation.

Furnace No. 62 has very low flame-radiation readings. It is difficult to understand how this furnace ever made the first heat in 18 hours 55 minutes with such low readings.

Low flame-radiation readings are always noted on old furnaces when the regenerators become worn or covered with flue dust, thereby failing to preheat the incoming air. Observed flame-radiation readings on an old furnace, prior to rebuild, will indicate the amount of regenerators that should be renewed in order to restore the furnace to its original position of maximum flame radiation after the rebuild.





Figures 13 and 14 — These sketches show the desirable flame position for high radiation factors and high production in the furnace illustrated.

TABLE I — Open Hearth Flame Radiation Readings

(Normal Operation)

Shop	Furnace	Gallon oil per hour	Cu ft air per minute	Pounds steam pressure — north and south ends											
				N-100		S-100		N-80		S-80		N-60		S-60	
				1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door
1	58	430	11,000	97	91	100	95	92	90	96	92	88	85	92	92
1	59	400	12,000	98	92	100	90	91	93	100	93	92	86	96	94
1	60	420	12,600	90	90	88	92	87	89	87	90	84	81	82	87
1	61	430	12,600	100	96	87	98	94	94	72	84	93	87	75	80
1	62	430	11,000	90	90	93	93	90	90	90	94	80	88	87	90
1	63	380	.....	92	90	85	90	86	87	86	90	82	88	82	87
1	64	410	.....	85	87	92	90	82	88	89	82	80	87	82	90
1	65	410	.....	92	92	90	89	79	89	87	91	71	86	75	84
1	66	430	12,400	94	92	100	90	96	93	99	90	86	91	92	86
1	67	450	12,600	94	86	94	90	91	87	88	87	87	86	84	83
1	68	340	12,000	98	84	100	88	95	83	100	90	90	84	97	90
1	69	425	12,600	99	83	100	88	96	85	98	87	88	82	89	87
2	71	470	13,200	98	86	100	83	95	91	96	89	91	92	88	89
2	72	470	13,200	98	96	92	82	94	96	87	92	87	90	82	90
2	73	380	14,300	94	80	98	91	91	84	93	92	85	80	87	92
2	74	420	13,000	94	90	92	87	92	92	88	90	83	90	84	89
2	75	380	13,200	100	91	98	92	100	91	94	95	88	90	86	93
3	79	460	14,500	97	94	98	87	88	92	93	86	84	88	86	87
3	80	460	15,400	91	88	96	88	89	89	92	89	79	86	85	87
3	81	390	14,400	98	84	95	88	96	84	90	87	86	86	85	82
3	82	400	15,400	100	91	100	88	98	93	97	92	92	93	92	90
3	83	410	14,500	94	84	92	87	91	85	86	87	86	82	92	91
3	84	490	14,300	89	90	90	90	86	90	84	88	85	85	80	82
3	85	480	14,500	98	96	92	94	86	93	85	91	82	86	76	86
3	86	420	15,300	90	88	92	92	86	87	88	91	79	83	80	85
3	87	400	15,300	91	90	96	94	88	88	92	93	..	91	86	91

TABLE II — Open Hearth Flame Radiation Readings

(First Heats After Repairs)

Furnace	Type of Repair	Time-charge to tap	Gallons oil per hour	Cu ft air per minute	Pounds steam pressure — north and south ends											
					N-100		S-100		N-80		S-80		N-60		S-60	
					1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door
62	Rebuild	18 hr, 55 min	410	11,000	80	68	69	74	77	65	64	75	69	66	57	81
66	Rebuild	14 hr, 50 min	430	11,000	86	76	78	77	82	79	65	78	76	78	74	79
73	Rebuild	13 hr, 40 min	400	12,600	79	82	86	88	78	83	84	90	72	80	76	85
74	Quick roof	19 hr, 25 min	470	14,000	84	89	79	88	80	90	81	86	71	84	76	83
79	Quick roof	19 hr, 37 min	490	14,200	79	87	82	83	78	89	80	87	73	84	72	82
82	Quick roof	20 hr, 54 min	480	14,500	74	81	86	79	74	81	78	83	70	76	74	77
86	Quick roof	11 hr, 5 min	500	14,600	75	86	92	87	64	80	86	84	64	74	76	82

TABLE III — Open Hearth Flame Radiation Readings

(Effect of Oil and Steam Temperatures)

Furnace	Gallons oil per hour	Cu ft air per minute	Oil temperature	Steam temperature	Pounds steam pressure — north and south ends											
					N-100		S-100		N-80		S-80		N-60		S-60	
					1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door
80	500	14,200	185° F	385° F	88	86	92	86	83	89	87	88	74	87	82	87
80	500	14,200	220° F	550° F	87	86	90	88	84	88	86	87	76	84	81	84
80	500	14,200	185° F	385° F	87	95	92	90	82	94	90	93	82	92	87	90
80	500	14,200	220° F	550° F	86	92	89	90	81	92	88	90	80	87	80	83
80	500	14,200	185° F	385° F	85	88	88	82	90	80	87	84	82	84	84	86
80	500	14,200	220° F	550° F	92	88	93	84	85	91	89	84	81	89	84	86

TABLE IV — Open Hearth Flame Radiation Readings

(Effect of Atomization Agents)

Furnace	Atomizing agent	Gallons oil per hour	Cu ft air per minute	Pounds atomizing pressure — north and south ends											
				N-100		S-100		N-80		S-80		N-60		S-60	
				1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door
60	Steam	400	12,400	92	80	94	90	98	88	90	90	89	85	90	89
60	Steam	400	12,400	97	80	90	87	97	82	92	90	90	88	88	92
60	Steam	400	12,400	91	85	95	88	94	92	89	91	91	90	86	87
60	Air	400	12,400	100	93	100	85	96	95	96	85	92	92	90	93
60	Air	400	12,400	102	81	98	99	102	84	99	99	96	92	97	100
60	Blast fce. gas	400	12,400	100	88	102	96	101	88	96	99	92	..	88	96
60	Blast fce. gas	400	12,400	96	77	94	83	92	82	97	85	93	86	88	90

RELATION OF FLAME RADIATION — TEMPERATURE OF STEAM AND OIL

Many open hearth operators have tried the use of high temperature steam and oil in an effort to create higher flame radiations. Table III shows six sets of readings taken in pairs on three different heats of the same furnace. Oil at 185 F and steam at 385 F were used alternately with oil at 220 F and steam at 550 F. The Btu of the mixture of oil and steam per gallon of oil above 60 F is 3527 and 3859 respectively, based on 2½ lb of steam per gallon of oil. Very little difference is shown between these two oil and steam conditions.

It is believed, however, that a larger burner nozzle area for the high temperature oil and steam conditions would result in a higher flame-radiation effect than shown in these tests. This is based on the fact that less steam is used on the higher temperature conditions when operating at the same pressure.

RELATION OF FLAME RADIATION — ATOMIZING AGENTS

The three atomizing agents most commonly used for fuel oil are steam, air, and blast furnace gas. Table IV shows the relative flame radiation readings, all taken on furnace No. 60, by using these three atomizing agents.

The steam in the main was 135 lb gage at 385 F and was reduced to the pressures indicated on the chart. The compressor for air and blast furnace gas was located at the furnace and delivered the gases at a heat of compression of 320 F, for 100 lb pressure. Gas and air flow at 100 lb pressure was 16,700 cu ft per hr.

According to the tabulation, compressed air gives the highest flame radiation readings, compressed blast furnace gas is a close second, and steam atomization third.

These tests were made with the same mixer and burner for all three atomizing agents. It is altogether possible that an increase in the size of the burner nozzle for

air and blast furnace gas atomization would give still higher flame radiation readings.

Furnace No. 60 was on its 80th heat after the rebuild, when the tests were run. The furnace was making good time, as the average of the last 20 heats was 8 hr 24 min from charge to tap. Compare this time to the flame radiation readings taken on steam atomization as shown by the tabulation. The furnace is estimated to be a "second class" furnace with minimum flame-radiation factor readings between 89 and 86 for steam atomization. This performance shows what can be done when a furnace is capable of producing high flame-radiation readings.

The tests indicate that there is considerable merit in the use of compressed air and blast furnace gas for atomization. Special emphasis should be given to the design and testing of mixers and burners for these two gases.

RELATION OF FLAME RADIATION TO OIL FLOW AND STEAM PRESSURE

Table V shows flame radiation readings taken at 100, 80, and 60 lb steam pressure, respectively. The readings on each of these charts were plotted separately, and a composite chart of all was then prepared, to show the trend of flame radiation as affected by oil flow and steam pressure, for a "first class furnace." This chart is shown by Figure 15. It may be noted that the flame radiation readings at the second door are higher than those at the first door for oil flows of 500 to 460 gal per hr, and that the first door is higher than the second door for flows of 460 to 300 gal per hr. For maximum heat transfer and furnace efficiency the first door flame radiations should be equal to or greater than the second door readings. This means, for the particular burner, mixer, and furnace design in question, that oil flows exceeding 460 gal per hr are inefficient, and that the burner area and mixer capacity should be increased so that more steam could be used above 460 gal of oil per hr.

CONCLUSION

The average tons per hour per furnace can, in most open hearth shops, be increased by a thorough knowledge of flame-radiation readings.

Readings taken regularly on all furnaces will be most enlightening; and, in most cases, the factors causing

TABLE V — Open Hearth Flame Radiation Readings

(Fixed Operation)

Shop	Furnace	Pounds steam pressure	Cu ft air per minute	Gallons oil per hour — north and south ends											
				N-500		S-500		N-400		S-400		N-300		S-300	
				1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door	1st door	2nd door
3	79	100	14,500	93	94	93	88	95	88	98	84	96	72	100	71
3	80	100	14,500	82	86	87	88	85	84	94	85	90	72	96	74
3	82	100	14,700	88	89	95	92	90	82	98	84	93	72	98	73
3	84	100	14,800	92	93	92	96	96	90	94	88	98	72	98	72
3	85	100	14,800	90	98	86	93	98	92	94	91	100	77	99	80
3	86	100	14,500	92	96	95	98	96	87	100	91	97	78	100	81
3	87	100	14,500	84	91	91	90	87	87	100	81	93	82	100	82
3	79	80	14,500	80	90	84	90	86	86	92	87	93	78	96	78
3	84	80	14,500	92	91	82	90	96	86	89	88	98	73	88	76
3	85	80	14,500	80	92	83	90	90	93	89	89	92	83	94	83
3	87	80	14,500	85	95	87	91	85	97	93	90	91	89	94	82
3	82	80	14,300	84	86	87	87	87	85	87	83	92	78	90	74
3	81	80	14,800	86	85	76	82	90	80	84	80	87	84	84	67
3	82	80	15,200	82	90	90	91	88	89	93	87	94	87	94	74
3	79	60	14,500	77	82	80	84	88	82	85	78	94	77	92	77
3	84	60	14,500	86	91	80	84	90	88	86	88	94	77	90	84
3	82	60	14,500	78	84	84	83	82	84	86	84	85	80	90	78
3	82	60	14,800	80	76	80	81	83	79	82	80	85	73	89	81
3	84	60	14,500	81	85	81	78	84	82	77	75	86	74	77	68
3	79	60	15,000	82	85	81	83	87	88	88	80	90	75	90	71
3	81	60	14,800	84	90	82	85	86	89	84	85	94	88	92	86

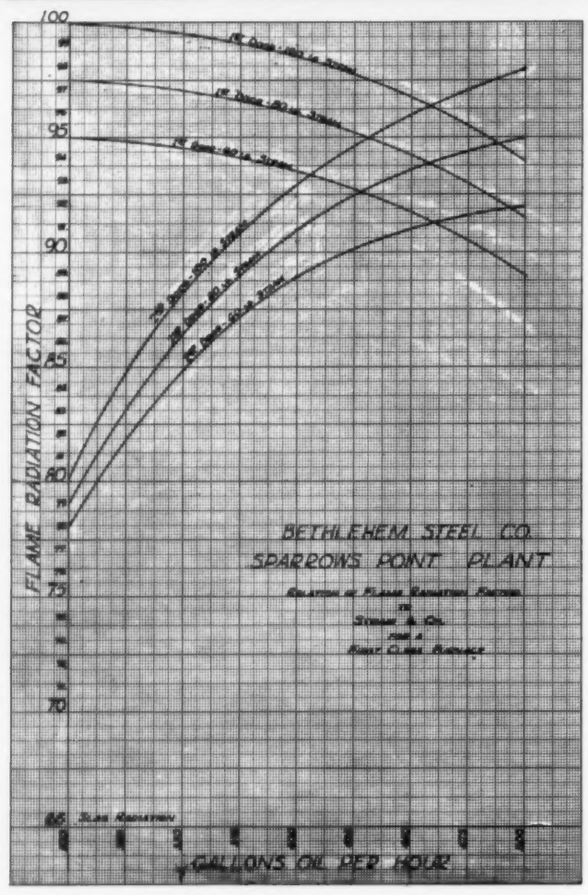


Figure 15 — Chart showing relations between flame radiation factors, rates of oil flow, and atomizing steam pressures.

slow or fast operating furnaces will in a short time become self-evident.

Under normal circumstances furnaces with large regenerators should have little difficulty in establishing flame-radiation readings of 100. However, for furnaces with small regenerators and low air preheat, additional means for getting the high readings will undoubtedly have to be resorted to, such as fuels of higher carbon content and or the use of preheated air or blast furnace gas for atomization.

The job of taking flame radiation readings may be combined with checking the roof temperature or heat potential element recorder. It will become increasingly important to have the furnace heat potential recorder accurate at all times when high flame radiation readings are achieved, in order to prevent excessive refractory wear. The two jobs will fit nicely together and can be done at one time by the same man using one instrument only.

The installation of permanent equipment in each shop for observing the flame radiation on each heat, prior to tapping, will give the shop superintendent sufficient information to guide him as follows:

1. Flame-radiation readings will enable the shop superintendent to fill out his schedule cards on each furnace and to make changes in these cards as the furnace campaign progresses.

2. Flame-radiation readings will provide sufficient information, ahead of time, to determine the necessary extent of regenerator rebuild.

3. Flame-radiation readings will provide the tangible data necessary to evaluate changes in design of burners, mixers, port construction, atomizing agents, etc., so that, eventually, all the furnaces in a shop will become standardized at their true maximum output.

DISCUSSION

PRESENTED BY

C. R. TAYLOR, Research Engineer, American Rolling Mill Company, Middletown, Ohio

A. J. FISHER, Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland

R. I. GUMAER, Fuel Engineer, Jones and Laughlin Steel Corporation, Aliquippa, Pennsylvania

M. J. BRADLEY, Leeds and Northrup Company, Philadelphia, Pennsylvania

P. F. KINYOUN, Combustion Engineer, Bethlehem Steel Company, Lackawanna, New York

F. E. LEAHY, Superintendent Fuel Department, Youngstown Sheet and Tube Company, Campbell Works, Youngstown, Ohio

E. E. CALLINAN, Combustion and Refractory Engineer, Steel and Tube Division, Timken Roller Bearing Company, Canton, Ohio

R. A. LAMBERT, Combustion Engineer, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania

W. C. BUELL, JR., Arthur G. McKee and Company, Cleveland, Ohio

C. R. TAYLOR: Mr. Fisher in his first paper (A. I. S. E. Yearbook, 1941, page 241) went to some lengths to separate flame emissivity and flame temperature. I would like to know what caused him to change his mind and go entirely to total radiation from flames.

A. J. FISHER: The radiation from the flame is a function of the temperature and the emissivity of the flame. These two items are difficult to measure separately. However, it is relatively easy to measure their combined effect.

R. I. GUMAER: I would be interested to know if Mr. Fisher has taken readings on mixtures of coke gas with oil or tar, or coke gas-blast furnace gas mixtures with oil or tar.

A. J. FISHER: We haven't taken any readings on coke gas. We have taken readings on pitches and tars, as indicated by the data given, but nothing has been done so far on coke gas.

M. J. BRADLEY: I should like to congratulate Mr. Fisher on the valuable information presented in his paper. I can appreciate the amount of work required

to obtain so much data, especially under the hot, difficult conditions encountered around open hearth furnaces. This information throws some light on the great mystery surrounding open hearth operation — why one heat melts rapidly, shapes up quickly, the furnace works just right and the heat taps out in a much shorter time than usual; while the very next heat (in the same furnace), may sag down instead of melting rapidly, requires a lot of work in shaping up, and drags along before tapping. Could it be that the flame condition gives a clue to the answer?

The rayotube used in making the determinations is of the mirror type. It is a standard commercial unit modified for this special application. For instance, a mica window is used in place of the usual quartz or glass window.

P. F. KINYOUN: Is there any reason why you can't use the optical pyrometer for the same yardstick or the same relation? In other words, we at Lackawanna talk about 3300, 3400 and 3500 F as flame temperatures.

At Lackawanna, we checked your instrument against the optical and used that as the yardstick in degrees F.

A. J. FISHER: The optical pyrometer can be used to approach radiation readings. The optical, however, is a measurement of temperature and does not measure the combined effect of temperature and emissivity. In addition to that, the optical is an instrument that has to be read by the human eye, and consequently the human element enters in.

In observing the flame, we travel the radiation tube through the flame and by recording at the same time, we are able to record the maximum radiation effect of the hottest spot. That is something that could not be done by the optical instrument. It would be too difficult and take too much time.

C. R. TAYLOR: Does the mica window have any purpose other than to keep the instrument clean?

M. J. BRADLEY: The rayotube has a compartment which contains the mirror and measuring elements. This compartment is sealed with a window to keep dust, fume, water vapors, etc., from depositing upon the mirror and measuring elements. The window dissipates a small percentage of the energy of different wave lengths. Usually the window is made from sheet quartz or glass. However, mica permits energy of longer wave lengths to enter the measuring compartment than either quartz or glass and is used on this application for this reason.

P. F. KINYOUN: If you establish the relative curves for the optical pyrometer as compared to the modified radiation tube, couldn't you reach a conclusion?

M. J. BRADLEY: It is possible that some of the results might seem to agree within reasonable limits under certain conditions. However, the fundamentals on which the two instruments are based and the quantities which they measure differ widely. The calibration of the rayotube is based on the total energy radiated under black body conditions, or, on an energy band comprising all wave lengths from 0 approaching 8 or 10 microns. The greater part of the energy it measures comes from the band beyond the visible or in the infra red region, while the calibration of the optical pyrometer is based on a particular wave band (approximately 0.65 micron) in the visible region of the energy band and measures brightness only. It seems to me that in this particular problem, we are more concerned with the total radiation (heating ability) regardless of whether it comes from the flame temperature, the flame emissivity or both. If this be true, it would appear that the rayotube meets the requirements better and should give more consistent results.

F. E. LEAHY: We are all interested to find out that some work has been done on developing a machine to measure the performance of an open hearth furnace at any period of its operation. I think one of the things that bother us at the present time is the difficulty of correctly evaluating operations at different periods. We have done some work with the roof temperature pyrometers, but one of the things we have had difficulty with was to find a way to get the machines stabilized and get capable men to keep them in proper working condition and calibrated.

Using a machine of this type which is a great deal more technical in its manipulation, I was just wondering what it would require in the way of skilled operators to make certain that the observations taken were correct and interpret them for the operators.

I was also interested to learn of the measurements and the various changes made in fuels and atomizing agents.

I know there are many problems that can be answered with such a machine as this, and I am sure as a laboratory instrument many of us would like to have it. I am wondering how many have the skill and are now prepared to apply such a machine as this to everyday operation. I think Mr. Fisher has worked this out in a splendid manner, and I think we are all anxious to find out how we can take advantage of this work.

E. E. CALLINAN: I think the point Mr. Leahy makes is very true, that probably the bulk of us do not have sufficient control of our furnaces at the present time so that this could be applied to the extent that Mr. Fisher has already applied it. However, it is a very educational thing to be able to realize, probably not quantitatively, but qualitatively, the importance of the factors which Mr. Fisher has brought out, and from that point this has been a most valuable contribution.

R. A. LAMBERT: In your studies, did you make any studies of the variations of super-heated steam temperatures, and the relation that had to the radiation factor? Did the factor increase or decrease as the superheat became greater on the steam supplied for atomization?

A. J. FISHER: We show the chart indicating that study between 385 F steam and 175 F oil, and 220 F oil and 550 F steam. Between those readings there was no appreciable difference, using the same pressures on the atomizing mixers to the burners.

R. A. LAMBERT: When you speak of steam pressure, do you mean the pressure at the reversing stand or at the atomizer?

A. J. FISHER: At the atomizer.

W. C. BUELL, JR.: Mr. Fisher's first paper (A. I. S. E. Yearbook, 1941, page 241) was a notable document, presenting a novel and timely clinical analysis of the development, action and effects of oil flames in open hearth furnaces.

However, as is generally the case in the initial presentation of a new subject, the author dealt with the

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abstract science involved, and left us rather out on a limb as to how this new science could be properly applied to our steel making technique.

In the light of this subsequent paper, it is evident that the author has had the practical application of the new science ever in mind, for in this document he steps down from the pedestal of the scientist to the plane of the technologist, and tells us not only how the theory may be translated to practice, but concretely shows us how to do it.

The Fisher index of flame radiation and the apparatus for determining this factor is a definite contribution to operating effects, particularly in that it offers the operators a new tool for the control, measurement and recording of the most elusive factor of open-hearth operation; the efficiency of certain flame characteristics during given periods of a heat as well as a means of duplication of flame conditions, after proper conditions have been found and established.

Through the lack of a method of doing otherwise, flame in present practice is adjusted by the eye of the operator to what he considers best effect under conditions then prevailing. The circumscribed human eye, particularly when further limited by covering of ray retarding glass, has little chance of getting the best from a medium that emits within both limits of the known spectrum.

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Immersion Heating -

DETERMINATION OF FLUE TEMPERATURES

. . . . . the paper offers a method for direct calculation of fuel gas temperature in immersion heating . . . . such determinations aid in selecting the proper size of equipment without "cut and try" methods . . . . .

by H. C. McRae

RESEARCH ENGINEER

THE NORTH AMERICAN MFG. COMPANY

CLEVELAND, OHIO

▲ BY immersion heating of liquids in tanks is meant the application of heat from combustion internal to the liquid. In other words the combustion chamber is surrounded by the liquid to be heated. Figure 1 shows a typical example of a tank being heated by an immersion burner. The burner is fired into a pipe which is submerged below the level of the liquid to be heated. High combustion efficiency is possible due to good heat transfer between the hot flue gases and the cold pipe wall. One advantage of immersion heating over external heating methods is the greater amount of heating surface which may be obtained.

There are three general methods of firing: (1) open type atmospheric burners, (2) open type pressure burners, and (3) sealed-in pressure burners. The atmospheric burner is limited to relatively low input in a given pipe size in order to obtain sufficient secondary air. This means that higher temperatures cannot be obtained without occupying too large a part of the tank.

A specially designed sealed-in burner may be used up to rates approaching velocities of forced convection. Where only short pipe lengths are available, the firing rate must be kept low and excess air must be excluded to obtain efficiency; hence, the advantage of using sealed-in burners.

The open type pressure burner is best suited for general industrial purposes, since higher input may be obtained without too much loss in efficiency. Ease of lighting, observation, and mounting of safety controls are other advantages.

As in all other combustion operations, the fuel heat input is equal to the sum of the heat storage, heat losses and the flue losses. Heat losses from bare tank walls and insulated walls may be found in the literature. If a tank has a relatively large evaporating surface and the liquid is somewhat near its boiling point, the evaporation losses will greatly exceed the wall losses and hence insulation will not reduce the total tank losses appreciably. Figure 2 gives evaporation losses (not including radiation and convection losses from the surface) from the surface of water at various temperatures. Forced agitation of the liquid increases the evaporation appreciably. Both curves were obtained from experimental data. As the boiling point is approached, the surface becomes greatly agitated and evaporation losses increase rapidly.

During the period of time when the liquid is being heated up, there is a temperature gradient from the top to the bottom. If the temperature is measured at the surface, the body as a whole may only have been raised 80 percent of that indicated. At equilibrium conditions the temperature is uniform.

The third source of heat loss is in the flue gas. If the air gas mixture is proper, this resolves itself into evaluating the flue temperature. The derivation of this flue temperature, then, is the subject of this article.

The flue temperature depends upon the pipe length and diameter, as well as the rate of fuel input. The following is a derivation of flue temperature for free convection by well known laws of heat transfer.

Natural gas is used as the fuel and is premixed with

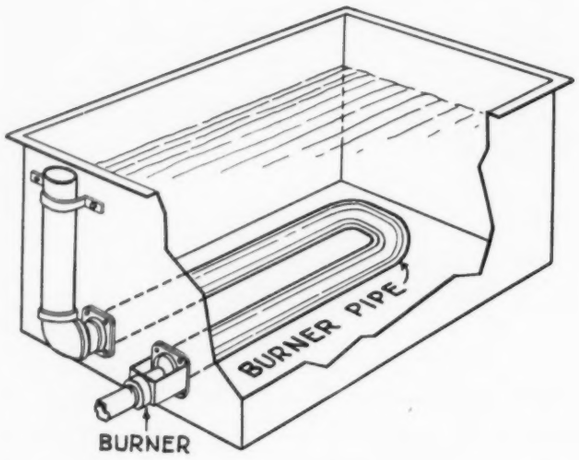


Figure 1 — Immersion burner installation.

the proper amount of air or 10.3 cubic feet to one of gas. Perfect combustion is obtained with ultimate percent carbon dioxide. (This is possible as it was proved by experiment.) Straight pipe is used. The resistance to heat flow of the pipe wall and water film is considered negligible, although there is a slight drop in temperature in the water film.

The inside pipe wall is considered to be at a uniform temperature of 200 F in water at an equilibrium temperature of 180 F. The true pipe wall temperature varies approximately from 300 F at the entrance approaching 180 F at the exit, but this change in wall temperature will have slight effect on the gas temperature. Combustion is taken to be instantaneous and complete in zero length obtaining a theoretical flame temperature of 3550 F. Actual combustion takes place in finite time and finite length. Theoretical temperature is never reached because heat is lost to the walls while the combustion reaction is taking place. The latter assumption, then, will introduce the greatest error.

Let —

d = inside pipe diameter in inches
f = gas flow rate in cubic feet per hour
l = pipe length in feet
t = flue gas temperature
x = t—200 or difference between gas and wall temperature
y = heat flow per unit area of inside pipe wall in Btu per hour per square foot.

The general method of solution is to, first, find empirical formulas for y_r and y_c, heat flow by radiation and convection as a function of gas temperature, gas flow rate, and pipe diameter, and then set up an integration equating heat lost by the gas and heat flow by laws of heat transmission. Solve this equation for gas temperature. Standard formulas for heat exchangers and logarithmic mean temperature differences cannot be used since they are based upon a constant heat transfer coefficient throughout the length of the heat exchanger. Due to the large change in gas temperature, both the radiation and convection coefficients (Btu per hour per square foot per degree F) of the gas film vary considerably.

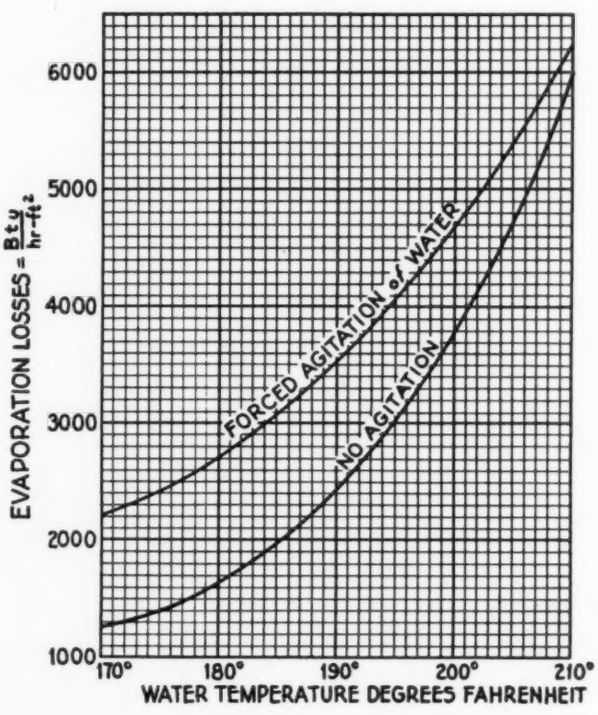
Heat flow by radiation of carbon dioxide and water vapor in the flue gas, assuming an emissivity of .7 for the inside pipe wall, may be calculated for various gas temperatures and pipe diameters, from charts prepared by Hottel and Guerrieri. Taking an equation of the type $y_r = (ad^2+bd+c)x(gd^2+jd+k)$ and solving for a, b, c, g, j and k from the values obtained from the above mentioned charts, yields:

$$y_r = (.0983d^2 - 1.39d + 7.28)\ (10^{-4})\ x$$

$$(-.00417d^2 + .075d + 1.867)\ \frac{\text{Btu}}{\text{hr-ft}^2}$$

Convection heat flow is a function of gas temperature, diameter, and gas flow rate. By limiting the maximum flow to a value of $G = 1650 \frac{\text{lb}}{\text{hr-ft}^2}$, the flow remains in the region of free convection rather than forced convection where the film coefficient is substantially independent of gasflow rate. Experiment seems to indicate that it is difficult to fire at a higher rate when using sealed-in burners.

Figure 2 — Chart showing evaporation losses, not including radiation or convection from surface.



From Nusselt's data on convection coefficients as a function of mass velocity, use a value of G = 1300 to obtain a good average value for h_c (Btu per hour per square foot per degree F) from the equation:

$$\frac{h_c D}{K} = (.020)\left(\frac{DG}{u}\right)^{.8}$$

D = pipe diameter in feet

K = conductivity of flue gas in $\frac{\text{Btu}}{\text{hr-ft-°F}}$

u = viscosity of flue gas in $\frac{\text{lb}}{\text{hr-ft}}$

When G = 1300, this reduces to

$$h_c = \left(\frac{10.20}{d^{.2}}\right)\left(\frac{K}{u^{.8}}\right) \text{ where d is in inches.}$$

At the higher flue gas temperatures the values of $\left(\frac{K}{u^{.8}}\right)$ are extrapolated and, fortunately, both numerator and denominator increase approximately in the same ratio, giving a value for $\left(\frac{K}{u^{.8}}\right) = .187$.

$$\text{This makes } h_c = \frac{1.906}{d^{.2}} \quad \frac{\text{Btu}}{\text{hr-ft}^2\text{-°F}}$$

$$\text{Therefore } y_c = (1.906)\left(\frac{x}{d^{.2}}\right)\frac{\text{Btu}}{\text{hr-ft}^2}$$

The total heat transfer is the sum of convection and radiation.

$$y = y_c + y_r =$$

$$\left(19.06\frac{x}{d^{.2}}\right) + (.0983d^2 - 1.39d + 7.28)\ (10^{-4})\ x^4$$

$$(-.00417d^2 + .075d + 1.867)\ \frac{\text{Btu}}{\text{hr-ft}^2}$$

This gives the heat flow as a function of temperature difference between gas and pipe wall, and the diameter only (x and d).

The mean specific heat of flue gas is —

$$c_p = .024\ \frac{\text{Btu}}{\text{ft}^3\text{-°F}}$$

For every cubic foot of natural gas there is 11.6 cubic feet of flue gas. This makes the rate of flow of flue gas equal to 11.6 of cubic feet per hour.

In Figure 3 an element of area along the pipe will equal to dA will have a heat flow of $ydA\ \frac{\text{Btu}}{\text{hr}}$.

The heat lost by the gas is

$$(11.6f)\ (.024)\ dx = .278f dx\ \frac{\text{Btu}}{\text{hr}}$$

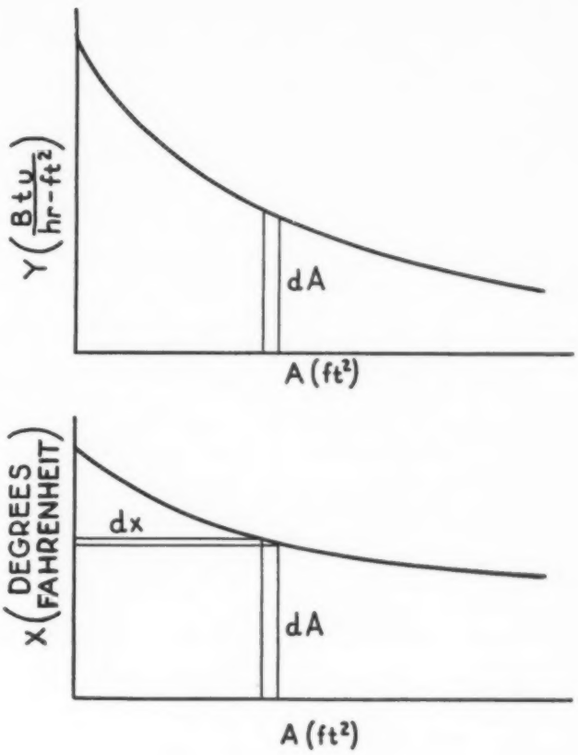


Figure 3 — An element of area along the pipe wall equal to d A will have a heat flow of y d A Btu per hr.

As A increases, both x and y decrease; use a negative sign when equating the above values.

$-ydA = .278f dx\frac{\text{Btu}}{\text{hr}}$, or in the form of definite integrals:

$$-\int_{A=0}^{A=A} \frac{3.60}{f}\,dA = \int_{x=3350}^{x=x} \frac{dx}{y} \quad \text{(Equation 1)}$$

Since A = (.262 l d) square feet:

$$-\int_{o}^{A} \frac{3.60}{f}\,dA = -.942\,\frac{l\ d}{f}$$

In the right hand member of equation 1 substitute the above value of y, integrate and solve for x. Since t = 200 + x:

$$t = 200 + \left[\frac{(d^{.2})\ (.0516d^2 - .729d + 3.82)\ (10^{-4}) + (3350)^{(.00417d^2 - .075d - .867)}}{e^{-(-.00749d^2 + .1346d + 1.556)\left(\frac{1d^{.8}}{f}\right)}} - (d^{.2})\ (.0516d^2 - .729d + 3.82)\ (10^{-4}) \right]^{\frac{1}{(.00417\ d^2 - .075d - .867}}$$

Rewriting equation 2 in more simple form—

$$t = 200 + \left[ae^{b\left(\frac{L}{f}\right)} - m \right]^{-n} \qquad \text{(Equation 3)}$$

Table I gives the value of d and a, b, m and n for standard pipe sizes.

Figure 4 is a graph giving the solution of equation 3.

When using the open type pressure burners at higher rates of forced convection, it is assumed that no excess air is induced or that none of the flue gas is lost at the entrance to the pipe.

Returning to Nusselt's equation for convection heat flow

$$\frac{h_c D}{K} = (.020)\left(\frac{DG}{u}\right)^{.8} \text{ where G is}$$

now greater than 1650 $\frac{\text{lb}}{\text{hr-ft}^2}$

This may be reduced similarly to that of free convection, resulting in

$$h_c = (.344)\left(\frac{f^{.8}}{d^{1.8}}\right)$$

$$\text{or } y_c = \left(\frac{.344f^{.8}}{d^{1.8}}\right) \times \frac{\text{Btu}}{\text{hr-ft}^2}$$

The radiation heat flow, y_r, is the same as before.

Integrate as before, only using the new value of y for forced convection.

Since y is now a function of f as well as x and d the solution is more complicated:

Writing equation 4 in more simple form:

$$t = 200 + \left[\left(\frac{a}{f^{.8}} + b\right) e^{r\left(\frac{L}{f^2}\right)} - \frac{a}{f^{.8}} \right]^{-n}$$

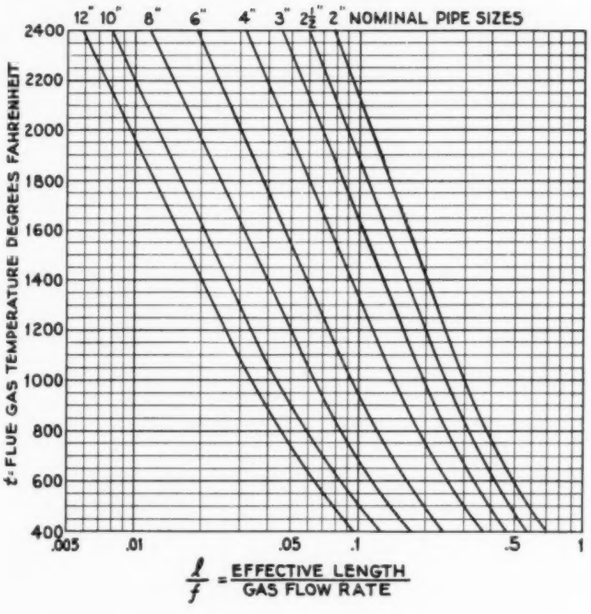


Figure 4 — Graph giving values as calculated with equation 3.

Since y is now a function of f as well as x and d the solution is more complicated:

$$t\ gas = 200 + \left[\frac{\left(\frac{d^{1.8}}{f^{.8}}\right)\ (.286d^2 - 4.04d + 21.17)\ (10^{-4}) + (3350)^{(.00417d^2 - .075d - .867)}}{e^{-\left(\frac{1}{d^{.9}f^{.3}}\right)(-.001352d^2 + .0243d + .281)}} - \left(\frac{d^{1.8}}{f^{.8}}\right)\ (.286d^2 - 4.04d + 21.17)\ (10^{-4}) \right]^{\frac{1}{(.00417d^2 - .075d - .867)}}$$

TABLE I

Pipe size, in.	d	a	b	m	n
2	2.067	.000582	3.22	.000294	.996
2½	2.469	.000519	3.79	.000280	.974
3	3.068	.000445	4.65	.000259	.945
4	4.026	.000359	6.03	.000228	.908
6	6.065	.000262	8.85	.000186	.856
8	8.07	.000254	11.42	.000196	.832
10	10.19	.000340	13.74	.000280	.836
12	12.09	.000496	15.39	.000418	.858

Table II gives the values of a, b, r, and n for standard pipe sizes.

Figure 5 is a chart giving the solution of equation 4. For the sake of clarity, the 10 in. and 12 in. pipe sizes are omitted.

Experimental tests were run using both the open type pressure burner and the sealed-in pressure burner. A high velocity thermocouple was used to measure true gas temperature.

In addition, orsat analyses and tank temperatures were taken to obtain a heat balance. Tests were made on both 2 in. and 3 in. pipe sizes. Measured temperatures were, in all cases, lower than calculated values. However, the "effective length" obtained from the

Figure 5 — Chart for graphical solution of equation 4, giving flue temperatures for forced convection.

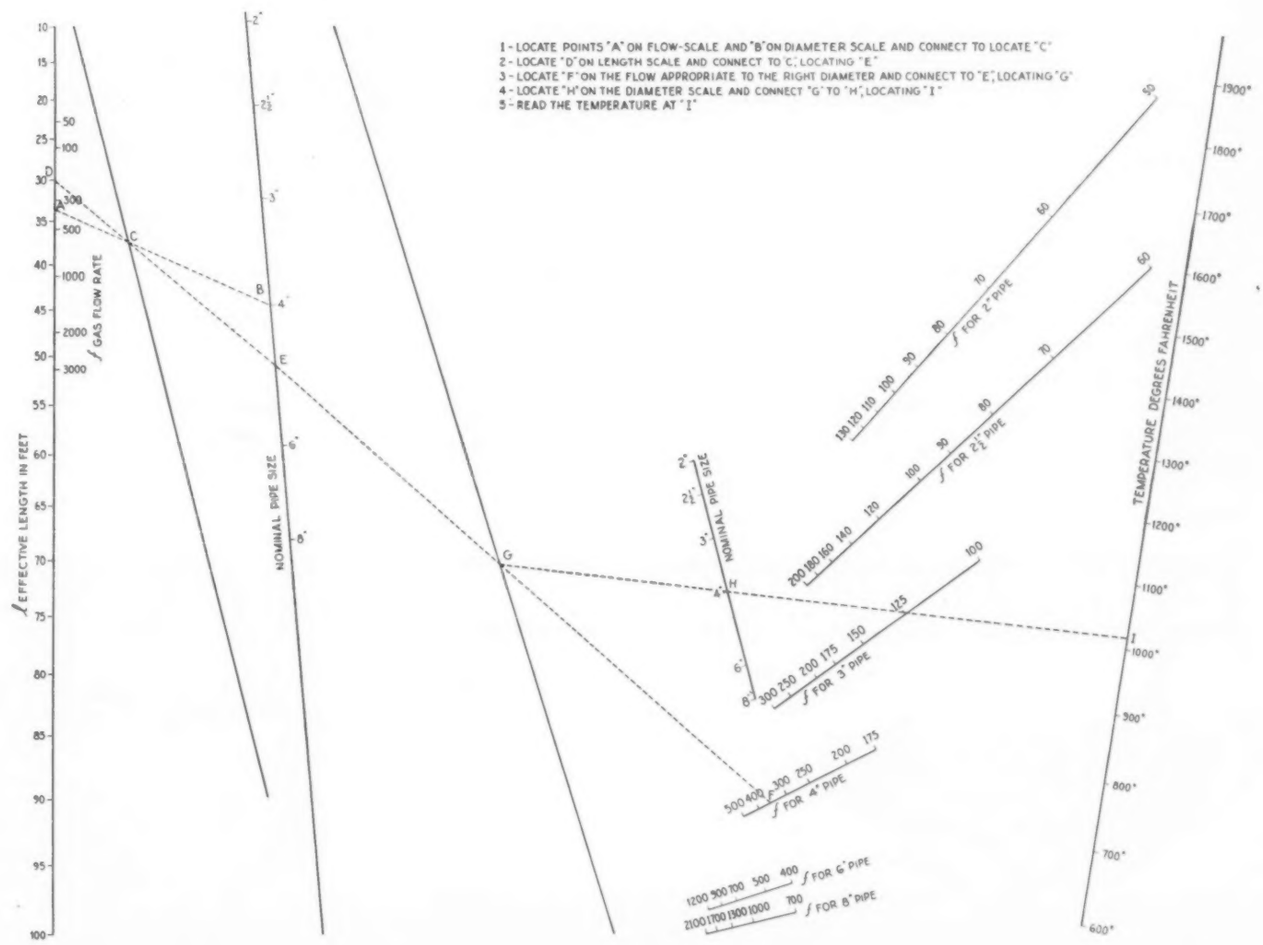

1 - LOCATE POINTS "A" ON FLOW-SCALE AND "B" ON DIAMETER SCALE AND CONNECT TO LOCATE "C"
2 - LOCATE "D" ON LENGTH SCALE AND CONNECT TO "C", LOCATING "E"
3 - LOCATE "F" ON THE FLOW APPROPRIATE TO THE RIGHT DIAMETER AND CONNECT TO "E", LOCATING "G"
4 - LOCATE "H" ON THE DIAMETER SCALE AND CONNECT "G" TO "H", LOCATING "I"
5 - READ THE TEMPERATURE AT "I"
EFFECTIVE LENGTH IN FEET
GAS FLOW RATE
NOMINAL PIPE SIZE
TEMPERATURE DEGREES FAHRENHEIT
f FOR 2" PIPE
f FOR 2½" PIPE
f FOR 3" PIPE
f FOR 4" PIPE
f FOR 6" PIPE
f FOR 8" PIPE

TABLE II

Pipe size, in.	d	a	b	r	n
2	2.067	.00520	.000288	.1820	.996
2½	2.469	.00658	.000239	.1610	.974
3	3.068	.00862	.000186	.1396	.945
4	4.026	.01174	.000131	.1171	.908
6	6.065	.01830	.0000759	.0901	.856
8	8.07	.0306	.0000582	.0733	.832
10	10.19	.0634	.0000603	.0607	.836
12	12.09	.1245	.0000782	.0517	.858

TABLE III

Pipe size, in.	Effective length, ft	Flow	Flue temperature, F	Flow	Flue temperature, F
2	15	46	840	92	1030
2½	20	65	750	130	925
3	25	100	700	200	925
4	30	175	770	350	1050
6	40	400	830	800	1140
8	50	700	825	1400	1130

formulas by substituting the measured value of the temperature, was found to be independent of the flow rate. The additional length necessary to be added to the actual measured length to calculate the true flue exit temperature was also independent of the length chosen.

All of this data indicates that beyond some point in the pipe, heat is transmitted and gas temperature lost according to the theory presented, but in the entrance to the pipe there is a higher flow of heat than calculated. This phenomenon may be explained on a basis of super heat transfer of flames beyond the normal radiation and convection transmission, which is an accepted fact.

When elbows are used in the pipe line, an equivalent straight length of pipe may be used to allow for total effective pipe length. From Reynolds' analogy between heat transfer and friction drop, the convection heat flow of the elbow may be derived from equivalent length of elbows in pressure drop application, but little gain in heat flow is obtained by radiation in the elbow. Experimental tests indicated a less equivalent length of elbows for heat flow than for pressure drop as predicted. Data taken on the effect of corebusters showed little gain in heat transfer.

Table III gives a guide to the relation of variables in immersion heating. The lower flows indicated are the minimum for forced convection. In other words, below these values use Figure 4 and above, use Figure 5.

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GATKE Moulded Fabric Bearings have proved that delays can be avoided and costly machine shop work eliminated.

From the largest, to the smallest roll necks, table rolls, Universal Couplings, Cranes and other tough service—GATKE Bearings are effecting improvements that are so tremendous they must be experienced for full appreciation.

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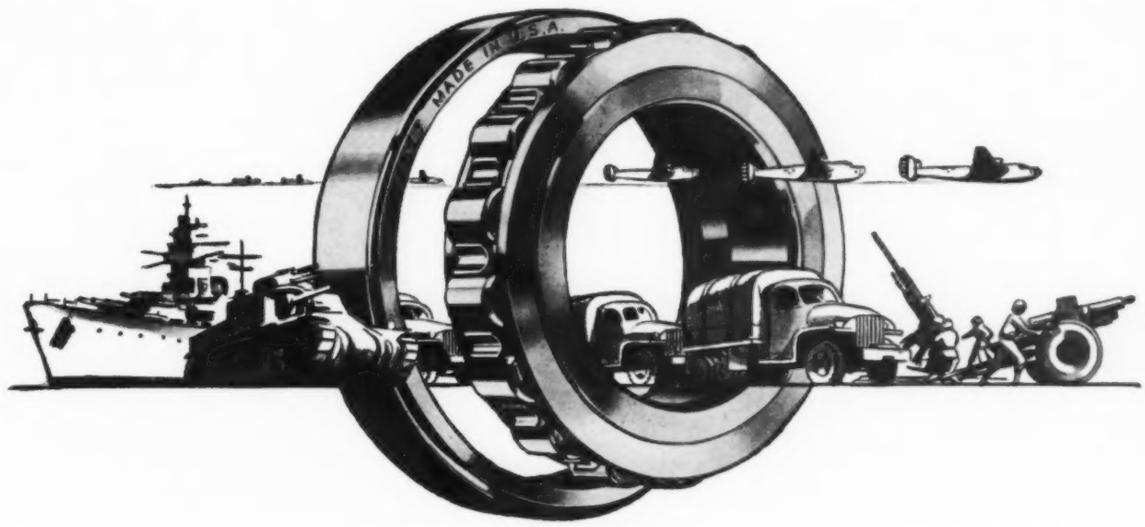

TODAY the heavily loaded shafts, gears and wheels of vital war equipment turning on Hyatt Roller Bearings, are well protected against shocks, excessive wear and breakdowns.

And other smooth rolling Hyatts, of the same microscopic accuracy and unyielding stamina, are serving round-the-clock in the machines which help build mighty guns and planes and tanks and ships.

Prolonging machine life . . . keeping equipment going . . . has been a job done well by Hyatts for the past fifty years. And after this war's won, there will be many more industrial, agricultural and transportation bearing applications in which Hyatts will continue to serve and save for another half century.

Is there any way we can help you now? Hyatt Bearings Division, General Motors Corporation, Harrrison, N. J.

HYATT ROLLER BEARINGS

Use This Check List

WHEN INSTALLING BRUSHES ON YOUR ELECTRICAL EQUIPMENT

1. See that all terminals are securely fastened to the brush holder support.
2. Remove dirt and grit from brush holders.
3. Provide $\frac{1}{8}$" to $\frac{3}{16}$" clearance between commutator and nearest portion of brush support in reaction and box type brush holders. Less clearance is sometimes preferable on small motors.
4. Keep angular position of all brush holders uniform with respect to the commutator.
5. Check neutral point and space the brush arms equidistant about the commutator.
6. See that toes of all brushes on each arm are parallel with commutator segment.
7. To prevent streaking of commutator, stagger brushes in positive and negative pairs.
8. Seat new brushes on commutators and rings accurately with sandpaper or a brush seating stone.
9. Adjust brush spring pressure to conform with manufacturer's recommendation.

Care exercised in the installation, fitting and adjustment of brushes increases life, improves performance and eliminates many of the possible causes of interrupted service.

NATIONAL TRADE-MARK *Carbon, Graphite and Metal-Graphite* BRUSHES

"National" brushes are doing their full share of carrying the enormous load demanded by the Nation's war effort. Essential requirements must be met first. Every effort is being made to satisfy all demands for our brushes in the shortest possible time.

Proper maintenance is paramount in keeping your electrical equipment operating at full efficiency. Many valuable and time saving suggestions as well as details of operations mentioned in the above check list are included in this series of "Modern Pyramids" bulletins. Copies are available promptly upon request.

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LET'S GO! U.S.A. KEEP 'EM FLYING!

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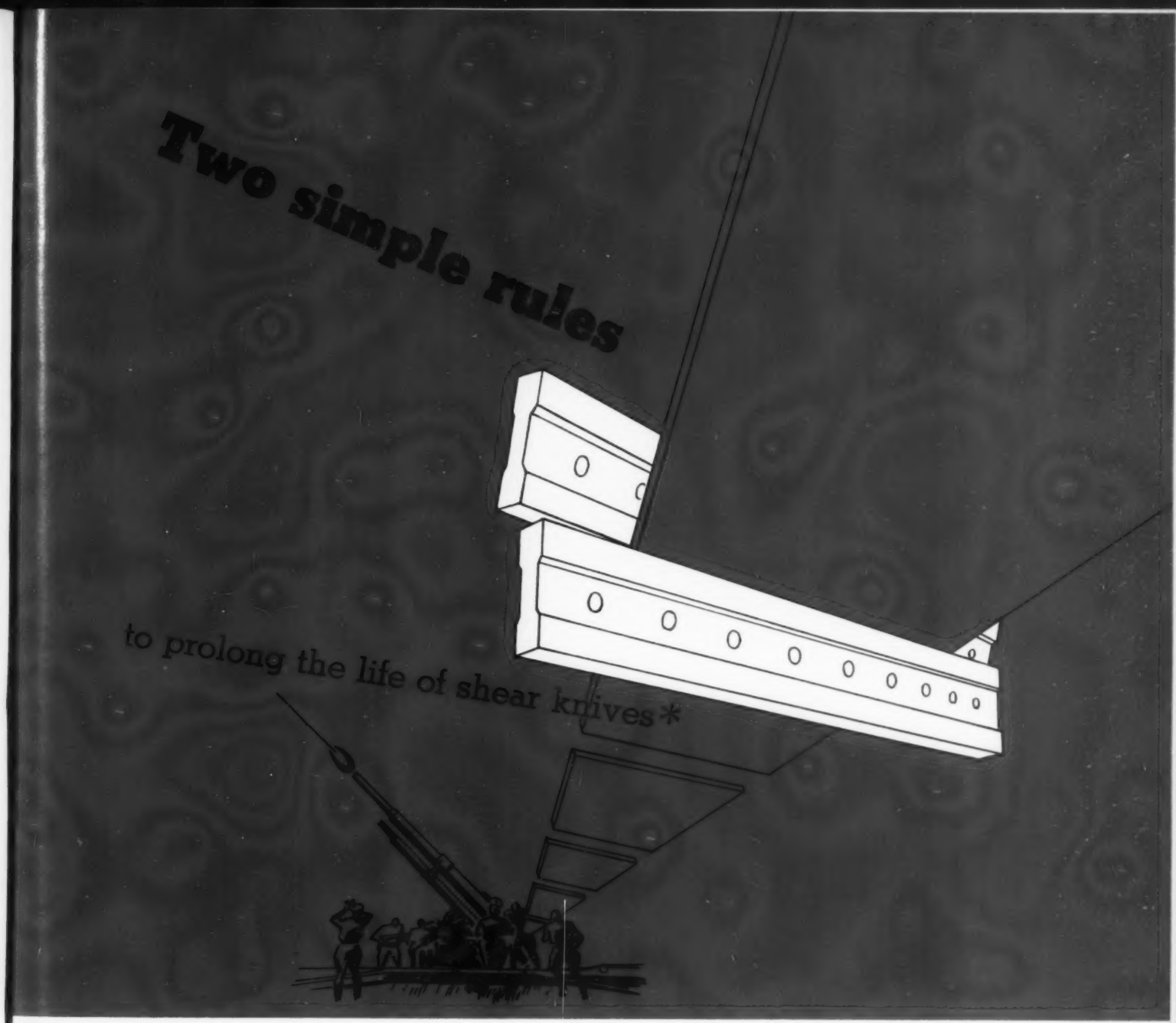
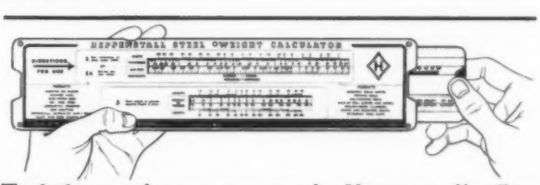


*Two things to keep in mind when you replace shear knives.

1 It's usually false economy to specify a set of knives to shear a thickness or hardness of steel for which they were not designed.

2 When the knives you order are placed in the shear, make sure the clearance between cutting edges is accurately adjusted for the thickness of steel to be cut.

Then remember this, too.
Because Heppenstall makes its own E.I.S. steel and has the largest facilities for producing solid tool steel shear knives, it can offer faster delivery at lower priority ratings. Add that to well-known diamond-H quality, and you have good reasons for specifying Heppenstall when your knives need replacement.



To help speed your war work, Heppenstall offers you this free steel-weight calculator. Write now—the supply is limited.

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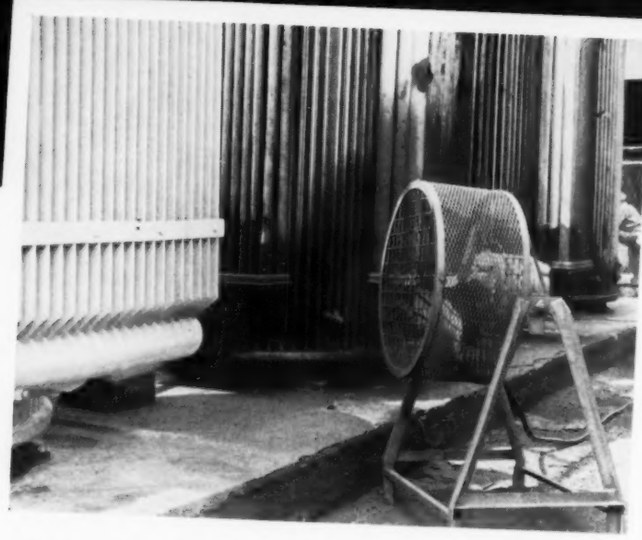
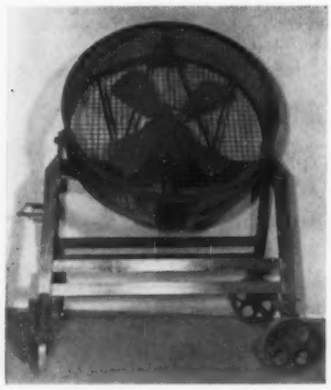
Help keep your workmen on their toes

Portable Fan No. TF-100, recognized as standard in many of the country's largest mills. Sizes from 12 in. to 36 in. in diameter.



Portable Fan No. TF-300 in operation, cooling large transformers in strip mill.

Crane Cab Fan, for cooling crane cab interiors and other confined areas. Available in 12 in. and 18 in. sizes, adjustable both horizontally and vertically.



Portable Fan No. TF-300W. Angle iron support adjusts for vertical or horizontal discharge through almost 360°.

It's more important now than ever before to keep your workmen comfortable. For comfortable workmen are more efficient, produce more work in a given time.

Truflo Fans can help you keep your workmen on their toes. All Truflo Fans are designed and built correctly for efficient, economical operation — they move more air per dollar. Write for free literature on any of the following styles:

Portable Cooling Fans • Crane Cab Fans
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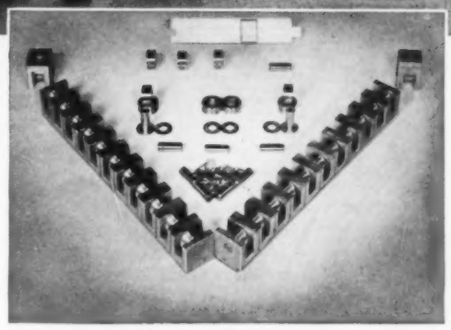
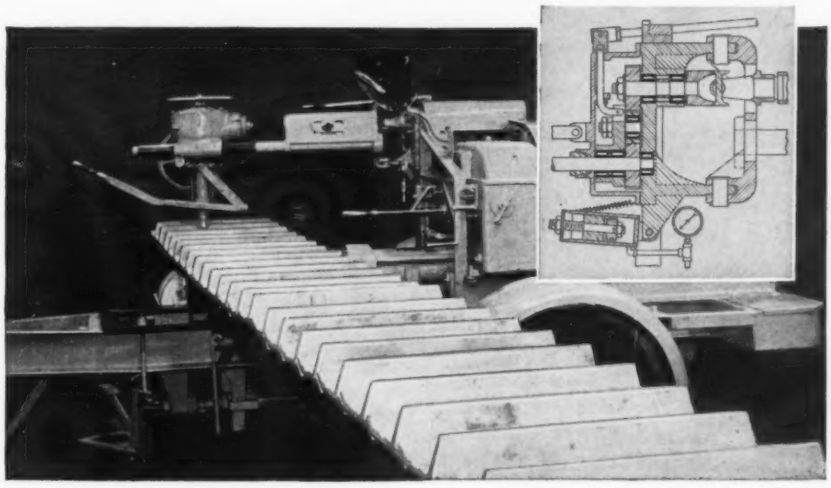
TRUFLO FAN COMPANY

554 MAIN STREET HARMONY, PA.

SIMPLER, MORE EFFICIENT PRODUCT DESIGN AND ASSEMBLY is often achieved by the use of special types of bearings such as these Bantam Journal Roller Bearings built for use in the crown and traveling blocks manufactured by Emsco Derrick & Equipment Co. Measuring 27½" O.D. they are provided with thrust shoulders built into outer races to eliminate hazardous thrust washers and contribute to compact design. Bantam's engineering and manufacturing facilities are geared for the prompt delivery of such special bearings for essential purposes.



"SEWING" SHEETS OF STEEL together rapidly with dependable welds to speed shipbuilding is the work of The Linde Air Products Company's "Unionmelt" welding machine. Special anti-friction bearings built by Bantam are used on the pressure and straightening rollers which feed the welding rod. These bearings, shown unassembled in the inset above, assure long, trouble-free service and are typical of Bantam's ability to provide bearings for special applications of all types.



LOW STATIC FRICTION of a Bantam Quill Bearing aids in actuating a safety-stop device on the cam-feed mechanism in this U. S. Tool Company "Multi-Miller," by allowing a normally stationary high-friction bearing on the camshaft and inside the Quill Bearing to turn when pressure on the shaft approaches the overload point.

EXPERIENCED SKILL TO SERVE YOU in the unbiased selection of standard bearings or in the design of bearings for unusual applications is offered by Bantam's engineers. Bantam makes every type of anti-friction bearing—straight roller, tapered roller, needle, and ball. No matter how difficult your bearing problem, TURN TO BANTAM.

UNLOOSENING ROCK-BATTERED BOLTS on the caterpillar tracks of tanks and tractors is the tough maintenance job performed by this track wrench, a product of Rodgers Hydraulic Incorporated. Despite the unusually heavy stresses encountered, dependable power transmission is assured by the high load capacity of eight Bantam Quill Bearings and four Bantam Needle Roller Bearings used in the gear mechanism. In addition, these bearings contribute to compact design because of their small size, as can be seen from the accompanying cross-section drawing, and to low power consumption because of efficient lubrication and low friction coefficient.

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STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL
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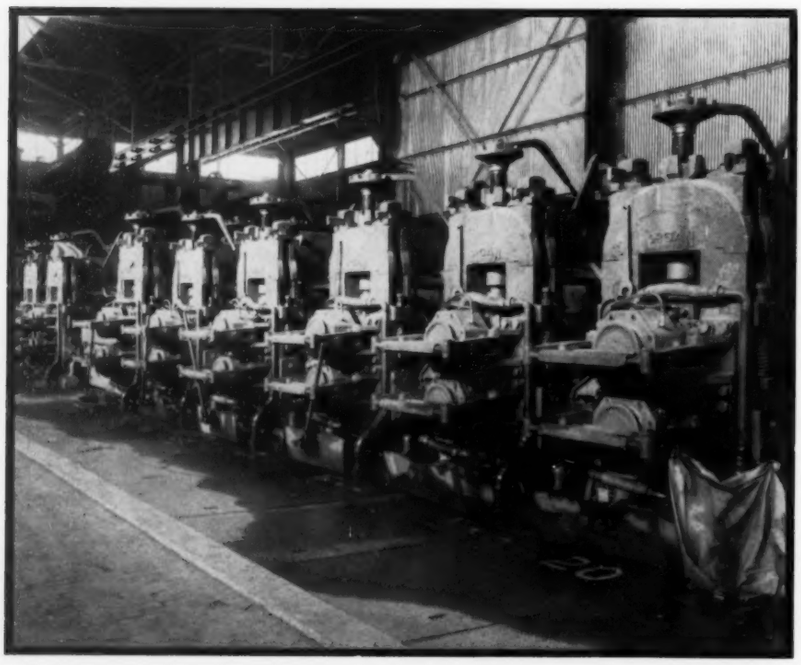
COLUMBIA STEEL STARTS OPERATION OF NEW ROD MILL AT PITTSBURG, CAL.

▲ Completion and full-time operation of Columbia Steel Company's new continuous rod mill at the Pittsburg, California Works, marks another finished step in the United States Steel Corporation's $700,000,000 war expansion program, Columbia Steel Company officials announced recently. Operation of the mill substantially adds to U. S. Steel's increasing finished steel facilities in the Pacific Coast area.

The new rod mill, the most modern continuous type built for three strand rolling in the United States, produces rods at a great speed. Rods produced from red-hot billets, thirty feet long, weighing six hundred pounds, pass through the last finishing stand to the reels at a rate of 48 miles per hour. At this speed, size No. 5 rod nearly a mile long is delivered to the reels in about a minute from the time the billet leaves the suspended arch-type furnace.

These roughing stands feed into six intermediate roughers and six finishing stands in the new continuous rod mill at the Pittsburg, California works of Columbia Steel Company, a subsidiary of the United States Steel Corporation.



Operation of this high quality production mill, which furnishes rods to the adjacent Columbia Steel wire mill, now humming day and night to fill wartime orders, is continuous from the time the cold billet enters the furnace to the placing of the finished bundle of rods on the shipping platform at the end of the mill.

Standard length billets of 30 feet are fed one by one into the upper end of the 33 x 50 ft furnace, pushing the entire row of billets down the inclined furnace bed. The furnace has an hourly heating capacity of 50 tons of billets, insuring a steady flow. All steel heating operations are automatically controlled from fuel mixture ratios to the temperature of the heated billet.

Billets are heated slowly and uniformly until reaching the proper rolling temperature. Billets are then pushed out, one by one, from the lower end of the furnace into the "bite" of the rolls of the first of nine roughing stands. In all, the mill has 21 stands, divided into nine roughing stands, six intermediate roughers and six finishing stands.

After leaving the final finishing stand, the rod passes through water-cooled connecting pipes to the reels. From the reels, the finished bundle of rods is switched onto an apron conveyor and headed toward the loading platform. At the end of this conveyor, bundles transfer automatically to a hook-carrier conveyor, designed to cool the rods before handling.

Rod bundles are removed from the hook conveyor by manually operated air hoists and placed on stands. Groups of coiled rods are then picked

Koppers "C & C" * Projects

*Current and Contemplated

The "tank that swims" must not stop

Bartlett Hayward Division

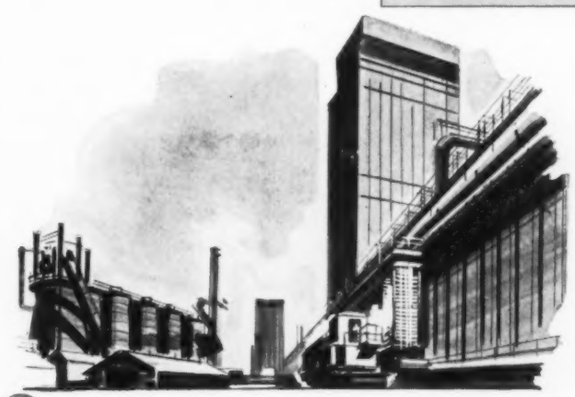
1 Current

Koppers Fast's Self-aligning Couplings drive the Army's "alligator boats." When these American amphibian tanks plow through the water toward an enemy shore and then crawl up out of the water and lumber across the ground, it is Koppers Fast's Couplings that transmit the dependable power that drives them on land and sea.

2 Contemplated

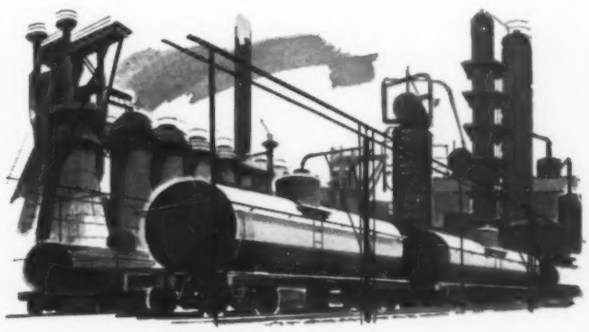
Koppers Fast's Couplings will drive more of industry's wheels. The load-bearing surfaces are protected against wear by a positive film of oil, kept permanently clean by rocking bearings which make precise, metal-to-metal contact in the one position where they form a dust and moisture-proof seal. Exclusive with Fast's.

Engineering and Construction Division



3 Current

Since Pearl Harbor, Koppers has built plants with annual tar-producing capacity of 23,000,000 gallons, and ammonium sulfate capacity of 30,000 tons; recovery and refining plants with a capacity of 8,000,000 gallons of light oil (including 1,500,000 gallons of toluol).



4 Contemplated

The world of coal tar chemicals is a constantly expanding universe. Chemists are finding new ways to use these materials in vitamins, medicinals, plastics, paints, varnishes, synthetic rubber, fuel, and other products—and providing a better post-war market for these steel mill by-products.

Koppers Company and Affiliates
Pittsburgh, Pa.

KOPPERS
THE INDUSTRY THAT SERVES ALL INDUSTRY

up from the stands by tractors and loaded on specially constructed flat cars for transfer to the Columbia Steel wire mill.

The new rod mill is a complete separate unit from the rest of the rolling mills and is served by its own auxiliary equipment. The roll shop for shaping and renewing the rolls is entirely modern in every respect. Seven of the nine main drive motors are housed in a separate motor room, which is air conditioned to remove the heat of the motors, protecting them from dust and other abrasives in the air. A water recirculating system is provided, made up of a settling tank, a clari-floculator tank, cooling tower, and suitable pressure pumps for returning the water to the mill, so that only make up water is required.

A quick roll change feature of the new rod mill is the conventional type of wobblers with the innovation of built-in universal drives on the coupling boxes and spindles, which minimizes loss of time for roll changes, together with smooth vibrationless running of the mill.

Other outstanding mechanical features of the new mill are:

1. The mill rolls are carried by fabric and ball thrust bearings adapted to the requirements of the job, according to the most recent experience in rolling mill equipment.

2. The size of rod ordinarily produced in the mill is 4½ gauge, but the mill is capable of producing No. 5 gauge up to and including 1 inch coiled rods.

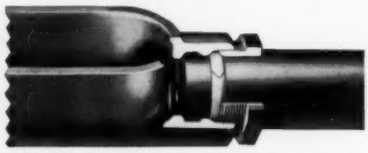
3. The control pulpit operator controls the speed, keeping the entire mill synchronized.

4. Rods are delivered from the finishing end of the mill at a maximum rate of 4,200 feet per minute.

NEW CONDULETS
for
Electrical Metallic Tubing
(Thin Wall Conduit)

Assembly of Conduit and Electrical Metallic Tubing

Exploded View of Conduit Showing "Fish-tail" Grip-Ring and Clamping Nut



Sectional View Showing Action of Nut and Grip-Ring on Electrical Metallic Tubing

- **A Complete Line**—Condulets to provide outlets for light, power, switching, junction boxes, etc.
- **Ease of Installation**—Simply insert the tubing and tighten the clamping nut, which has a broad hexagonal head easy to grip with any wrench.
- **Rigid Joint**—The compressed grip-ring bites into the tubing, providing a strong rigid joint.
- **Continuity of Ground**—Intimate contact provides a dependable raceway ground.
- **Internal Threads**—Safe from bruising in handling or installing.
- **Alignment**—Perfect alignment with existing rigid conduit installations.
- **Tubing Fit**—The accurately machined clamping nut assures a close fit with the tubing.
- **Sizes**—For electrical metallic tubing from ½-inch to 2-inch.

Send for Bulletin No. 2570 which contains complete listings of Condulets for electrical metallic tubing.

A Nationwide Distribution Through Electrical Wholesalers

MANUFACTURED ONLY BY
CROUSE-HINDS COMPANY
SYRACUSE, N. Y., U.S.A.
Offices: Birmingham—Boston—Chicago—Cincinnati—Cleveland—Dallas—Denver—Detroit—Houston—Indianapolis—Kansas City—Los Angeles—Milwaukee—Minneapolis—New York—Philadelphia—Pittsburgh—San Francisco—Seattle—St. Louis—Washington
Resident Product Engineers: Albany—Atlanta—Charlotte—New Orleans
CROUSE-HINDS COMPANY OF CANADA, LTD., Main Office and Plant: TORONTO, ONT.

MERGER OF BEARING MAKERS ANNOUNCED

▲ Bantam Bearings Corporation, South Bend, Indiana, a subsidiary of The Torrington Company of Torrington, Connecticut, for the past eight years, has been merged with its parent company and will henceforth be known as The Torrington Company, Bantam Bearings Division. The Bantam Division will retain its present personnel and continue its operations from the South Bend headquarters.

The merger makes available to industry, from a single company an unusually diversified line of anti-friction bearings. Bantam produces all of the major types with special emphasis on custom-built bearings in the larger sizes up to 12 feet in diameter. In addition, the combined facilities of Bantam and Torrington provide the manufacture of a complete range of needle bearings from a unified source. Bantam supplies both needle rollers and the unit-type Bantam quill bearing for medium to heavy requirements duty, while Torrington manufactures the Torrington needle bearing, also a unit type for generally lighter service or load conditions.

C. H. Talcott, sales manager of The Torrington Company's Bearing Division, will continue to direct sales of The Torrington needle bearing. Ray Nichols, vice-president and general manager of Bantam, will be in charge of the Bantam Division's operations while sales of needle rollers, quill bearings and other standard and special bearings will be continued under the direction of J. F. Oehlhoffen, sales manager of the Bantam Division.

Both Bantam and Torrington are exclusively engaged in producing bearings for the Nation's war effort and the Bantam Division has been awarded the Army-Navy "E" Flag with three stars for continued excellence of production for the Armed Forces.

FURNACE COMPLETES LONG PRODUCTION RUN

▲ After a record-shattering performance in iron production for the Chicago district of Carnegie-Illinois Steel Corporation, United States Steel Corporation subsidiary, one of a string of eleven blast furnaces at the corporation's vital South Chicago plant is being completely relined for the first time in seven years.

The furnace — the plant's No. 8 — was blown in March 29, 1936 and, with the exception of minor mechanical repairs, has been in constant operation until April 10. Its output of iron neared 3,000,000 tons during the seven year period.

In July of last year, the blast furnaces at the South Chicago plant poured out nearly 5,000 tons more pig iron during the month than had ever been produced before. Practically all of the iron was converted into steel all of which, since Pearl Harbor, has been destined exclusively for war purposes.

COMPANY CELEBRATES FIFTIETH ANNIVERSARY

▲ The Post-Glover Electric Company, Cincinnati, is celebrating its 50th anniversary this month . . . 50 years which have brought electrical industry from infancy to maturity.

The company was incorporated May 3, 1893, succeeding a previous partnership started in 1892. Since that time, first as a distributor, and later as a manufacturer, a diversity of electrical equipment and supplies has been furnished to industry.

More than 25 years ago, the company introduced the steel grid resistor. With its development other activities have gradually been curtailed, so that now they are engaged almost entirely in their manufacture.

Today the Post-Glover steel grid resistor is now in use by mines, mills, and railroads throughout the United States.

Present officers are: C. E. Nuckels, president; J. M. Van Winkle, vice president and secretary; E. A. Vosmer, Jr., treasurer; and J. H. Thiem, general superintendent.

TO CONSTRUCT NEW COKE OVEN BATTERY

▲ Announcement was made recently of the award of a contract by the Donner Hanna Coke Corporation of Buffalo, N. Y., to Koppers Company of Pittsburgh for construction of a battery of 15 Koppers-Becker type of by-product underjet coke ovens on the Donner Hanna site in Buffalo.

This will be the third battery built by Koppers at the Donner Hanna plant, two others having been erected in 1918 and 1930.

HAYS
GUARD PRODUCTION with HAYS
Series OT DRAFT or PRESSURE RECORDERS
Measuring units in the Hays Series OT Draft or Pressure Recorder are the famous Hays dry or diaphragm type which are extremely accurate under mill conditions.

BETTER PRODUCT CONTROL is possible with Hays Draft or Pressure Recorders which are a positive guide to balanced draft conditions in soaking pits, open hearths, slab mills, annealing and other furnaces. They eliminate guesswork, save man power and reduce rejects to the minimum. They are a real help in the all-out effort for bigger and better steel production.

The ten-inch, 24 hour charts give a permanent record of day in and day out performance of every furnace. Two draft values, two pressure values, two differential values or any combination of two of these three values may be recorded. Or temperature may be included if desired and mercury switches may be provided to operate an alarm or a power unit to open and close a damper, etc.

Any way you look at it, the Hays Series OT Draft Recorder is a Guard over furnace operation and merits your investigation. ***Write for Bulletin 39-232.***

The HAYS CORPORATION
SINCE 1901 COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

ELECTRONIC CONTROL FOR ADJUSTABLE SPEED DRIVES

▲ An adjustable-speed electronic motor drive has been developed by Westinghouse that can be used in any industry on applications that require constant preset speed at varying loads over a 20 to 1 speed range and smooth, automatic acceleration and deceleration. Flexibility of a direct-current motor drive with an alternating-current supply is obtained, as the incoming a-c power is converted by grid-controlled rectifier tubes and supplied to the armature and field of the d-c motor. This electronic drive provides constant torque for all speeds up to the base speed of the motor and constant horsepower above base speed.

The search for a satisfactory motor with exceptionally wide adjustable-speed range to operate from alternating current has continued ever since alternating current itself was first commercially used. Many solutions have been offered with some degree of success, for instance, numerous mechanical drives using a constant speed a-c motor and variable speed output shaft, modifications of the wound-rotor induction motor and slip clutch arrangements. Some industrial machinery is supplied by a separate source of d-c power, even if it means individual a-c, d-c motor-generator sets, so that a direct-current motor with its desirable characteristics might be used.

None of the special adjustable-speed, alternating-current drives for general purpose use are without some undesirable feature, whether it be speed range obtainable, speed torque characteristics, first cost, maintenance or mounting difficulties. In many instances where direct-current power is available, the standard direct-current motor does not completely fulfill all requirements; such as extremely wide stable speed range, good speed regulation and smoother automatic acceleration.

This electronic motor drive, known as the Mot-O-Trol, was designed to fulfill the desired requirements of an a-c, adjustable-speed motor. The basic idea is not new. Westinghouse has furnished such motor drives on special applications for some years, but recent refinements eliminate many of the earlier handicaps and make the new electronic system comparable or better than other existing solutions.

This electronic motor drive has many applications in the steel industry. For example, on straightening machines, cold or hot saw feed as well as on many material handling units.

Another step in the forward progress of electronic control is its use in adjustable speed drives.

ALLOY STEEL OUTPUT HITS NEW RECORD

▲ 16 per cent of all steels produced in March were of alloy grade — about three times the peace time percentage — H. G. Batcheller, Steel Division Director, pointed out recently.

Despite this increased production, larger demands traceable to expanded production of war machines necessitate strict conservation of the alloying elements, Mr. Batcheller said in a letter to all alloy steel producers.

After examining all proposed melting schedules for May, the steel division has suggested the use of the National Emergency alloy steels in many instances. Producers have been asked to notify the Steel Division if they are unable to comply with specific suggestions made in each case.

Mr. Batcheller's letter recalled that in the early days of the war effort, the demand for alloying elements to make conventional alloy steels was so great that it quickly became evident that steps had to be taken to curtail their use. This resulted in the development of nickel-chromium-molybdenum steels to utilize all types of scrap and to minimize the demand for any single alloying element.

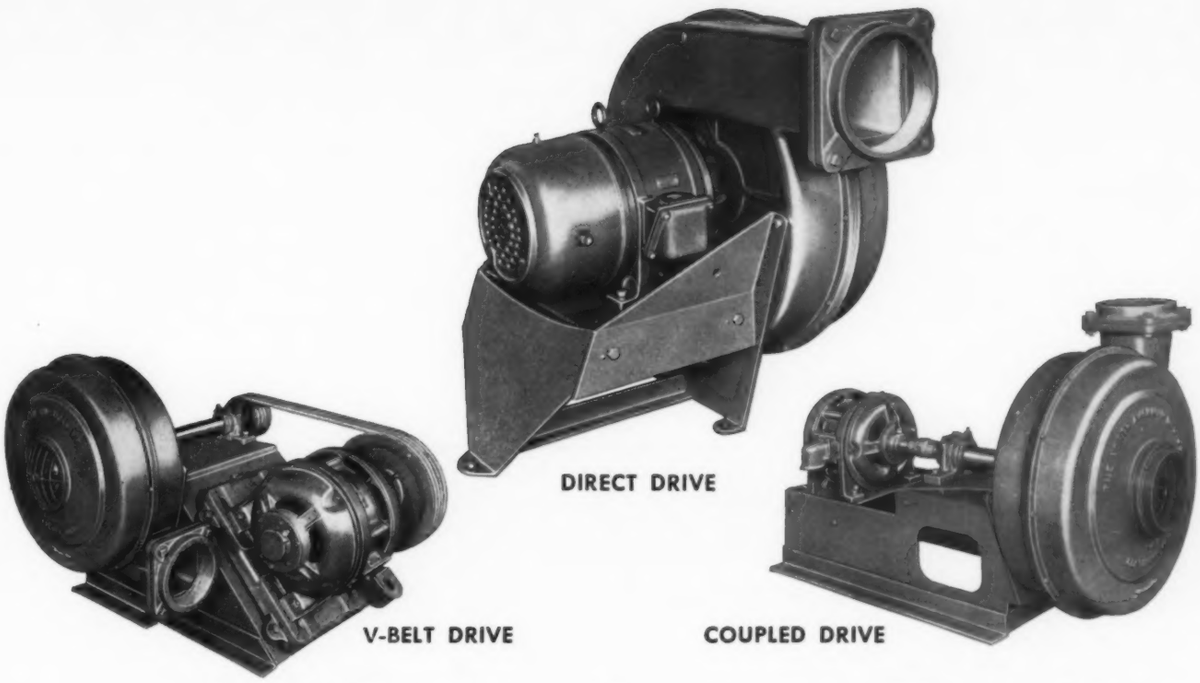
The NE alloy steels help solve difficulties arising from the fact that in the production of war machines there is a smaller amount of ingot weight actually utilized than in the production of peace time equipment. This results in a large increase in the amounts of solid scrap and turnings — containing valuable alloying elements — available for recharging into the furnaces. The National Emergency steels include the NE 8600, 8700, and 9400 series which use nickel, nickel-chromium, nickel-molybdenum, and other alloy steel scrap in their manufacture. These alloying elements are so adjusted in the composition of the steels as to give the proper hardenability and physical properties to make them equivalent to the conventional alloy steels previously used.

March alloy steel production amounting to 16 per cent of total steel production compares with normal peace time percentages ranging between five and six per cent. For the calendar year 1942, alloy steel production amounted to 13.1 per cent of all steels produced.

CONTROL SYSTEM USES SELSYN UNIT

▲ The Askania Regulator Company has just developed a new remote control device which combines the well established advantages of the jet pipe principle with the unique functions of a Selsyn motor.

By combining the Selsyn with the hydraulic jet pipe, the Selsyn move-



DIRECT DRIVE

V-BELT DRIVE

COUPLED DRIVE

Any Style—Large or Small!

NORTH AMERICAN
TURBO BLOWERS

ALL HAVE THE SAME SUPERIOR QUALITIES

STURDY CONSTRUCTION

Each NORTH AMERICAN Turbo Blower has a sturdy base of welded steel. The housings are of cast iron to insure rigidity and the gradual contours so necessary for smooth efficient flow of air.

SMOOTH QUIET OPERATION

The light weight, fabricated impellers are perfectly balanced, thereby guaranteeing quiet, vibrationless operation. Bearing failures disappear, since each NORTH AMERICAN Turbo Blower is carefully tested at the plant before shipment. Pressure, volume, balance, speed, current consumption and proper electrical characteristics of the motor must be correct before the Blower can be shipped.

EASY TO INSTALL

No special padding or special foundations are required when you install a NORTH AMERICAN Turbo Blower. In an emergency, however, you can change the position of discharge, disassemble or assemble the entire machine easily and quickly.

SIZE SELECTION

From long experience in combustion engineering, our Field Engineers know the correct volume and pressure necessary to make your job click. Let us save you money by recommending the right sized Blower for your job—not too large—not too small. NORTH AMERICAN Turbo Blowers are available from 4 oz. to 32 oz. and from 60 cfm to 4300 cfm. Write for our latest blower literature.

THE NORTH AMERICAN MANUFACTURING COMPANY

MANUFACTURERS OF INDUSTRIAL FUEL BURNING EQUIPMENT FOR GAS OR OIL

BRANCH OFFICES *with* FIELD ENGINEERS *in* PRINCIPAL CITIES

CLEVELAND, OHIO

ment need merely operate the sensitive jet pipe which is practically frictionless and thus transmit the original impulse through a hydraulic system with sufficient power to operate heavy dampers, butterfly valves or any other equipment requiring accurate remote operation.

The diagram illustrates how the movement of the Selsyn transmitter No. 1 is transmitted to the receiver No. 2 which in turn alters the position of the jet pipe No. 3, causing a greater hydraulic pressure to result on either side of piston No. 4. The amount of movement of the piston is always proportional to the amount of the original Selsyn motor movement.

The cylinder can be used to produce a proportional stroke, force or rate of turn proportional to the displacement of the transmitter Selsyn No. 1.

The factor of power, force or amplification is practically unlimited and accuracies of .2 per cent is obtained; greater accuracies can be provided when required.

For more details about the jet pipe principle, write the Askania Regulator Company, 1603 S. Michigan Ave., Chicago, Illinois.

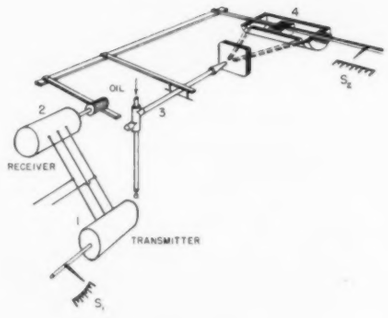
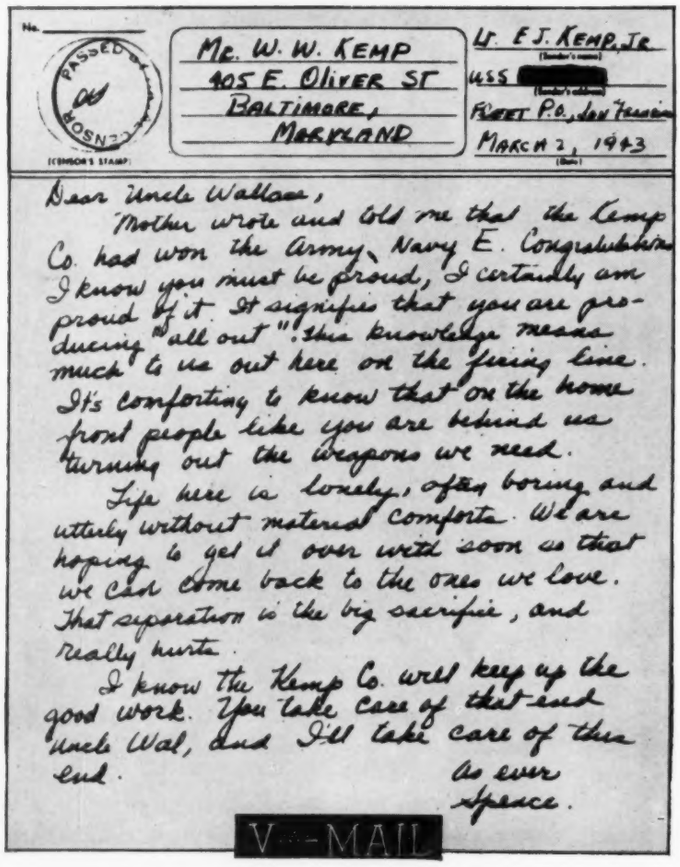


Diagram showing use of selsyn transmitter with hydraulic jet pipe in control system.

Friends of Kemp, both old and new, will be interested in this V Mail from the Front Line:


No.
PASSED BY CENSOR
Mr. W. W. KEMP
405 E. OLIVER ST
BALTIMORE,
MARYLAND
Lt. E. J. KEMP, Jr.
USS [redacted]
FLEET P.O., San Francisco
MARCH 2, 1943
Dear Uncle Wallace,
Mother wrote and told me that the Kemp Co. had won the Army, Navy E. Congratulations. I know you must be proud, I certainly am proud of it. It signifies that you are producing "all out". This knowledge means much to us out here on the fighting line. It's comforting to know that on the home front people like you are behind us turning out the weapons we need.
Life here is lonely, often boring and utterly without material comforts. We are hoping to get it over with soon so that we can come back to the ones we love. That separation is the big sacrifice, and really hurts.
I know the Kemp Co. will keep up the good work. You take care of that end Uncle Wal, and I'll take care of this end.
As ever
Spence.
V-MAIL

The Army-Navy "E" flag, awarded "for high achievement in the production of materials of war," proudly flies at The C. M. Kemp Mfg. Co.

KEMP of BALTIMORE

SYNTHETIC TIRES ON STEEL PLANT TRUCK

▲ Successful application of synthetic rubber to industrial tires in operation in one of the country's largest steel mills is reported by The B. F. Goodrich Company.

Four experimental tires, constructed entirely of synthetic rubber were built, two of the 22x16x16 and two 22x12x16. They are of the press-on type, for use on industrial power trucks and are being operated in the plants of the Jones and Laughlin Steel Corporation at Pittsburgh.

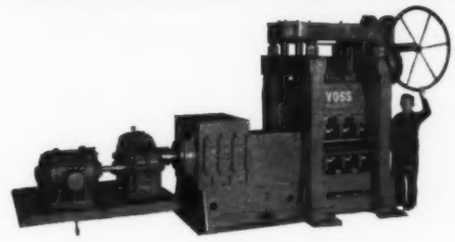
Latest reports on the tire performance is that they are holding up as well as tires made of natural rubber which previous to the rubber shortage were used in this type service.

IMPROVED LEVELER FOR ARMOR PLATE

▲ Now being built to handle armor plate, the latest improved Voss Ungerer roller leveler is performing a new and wider range of plate-straightening work.

Two machines of this size and capacity have just been completed by Voss Machinery Company, 2890 West Liberty Avenue, Pittsburgh, Pennsylvania.

This new ability to handle armor



This roller leveler will straighten armor plate up to ¾ in. thick. Designs for heavier material are also available.

plate is the result not only of heavier construction, but more especially of improvement in the design of the modern Voss straightener.

The machine pictured takes care of ¾ inch armor plate, in continuous sheets, and up to 1 inch in some other steels. It can also be designed and built for much heavier and wider plates. It has all the advantages and features of the former Voss Ungerer roller levelers, plus the new improvements and the ability to handle and satisfactorily straighten armor plates.

New Literature

▲ Based on material developed for the teaching of learners and apprentices of the Carnegie-Illinois Steel Corporation, "Fundamentals of Electricity" is an elementary treatise designed specifically for use in defense training classes at a beginning level. The material was rewritten to conform to the preinduction training course as prepared by the War Department. It is organized on the basis of a 90 period course and includes suitable laboratory exercises. Published by the American Book Company and containing 194 pages, the book is clear and concise, and offers a fine medium of training beginners in the elements of electricity.

▲ The rapidity with which industrial equipment is wearing out under record-breaking production, and the difficulty with which new parts and replacements are obtained, make the salvaging of such parts particularly attractive at this time.

Coast Metals, Inc., Canton, Ohio, in a 12-page booklet entitled "Hard-Facing with Coast Metals," sets forth the advantages of their patented Coast Metals for reclaiming and hard-surfacing worn machine parts. The booklet gives methods of application, properties of the welding rods, rod application, and examples of outstanding performance. It is available upon application to the company.

▲ A recent publication of the Keystone Electric Company, Baltimore, Maryland, entitled "Electric Motor Maintenance," describes ball bearing end bells manufactured by the company to replace all types of oil-lubricated plain sleeve bearings. Of varied size and design, the end bells will fit the different types of motors and will accommodate the different makes of ball bearings.

▲ "The need for reliable temperature data is best satisfied by balance-type instruments," says Leeds and Northrup Company, in the first headline of its new 36-page catalog; and the company proceeds to develop this

SAVE MANPOWER HOURS

PHILLIPS

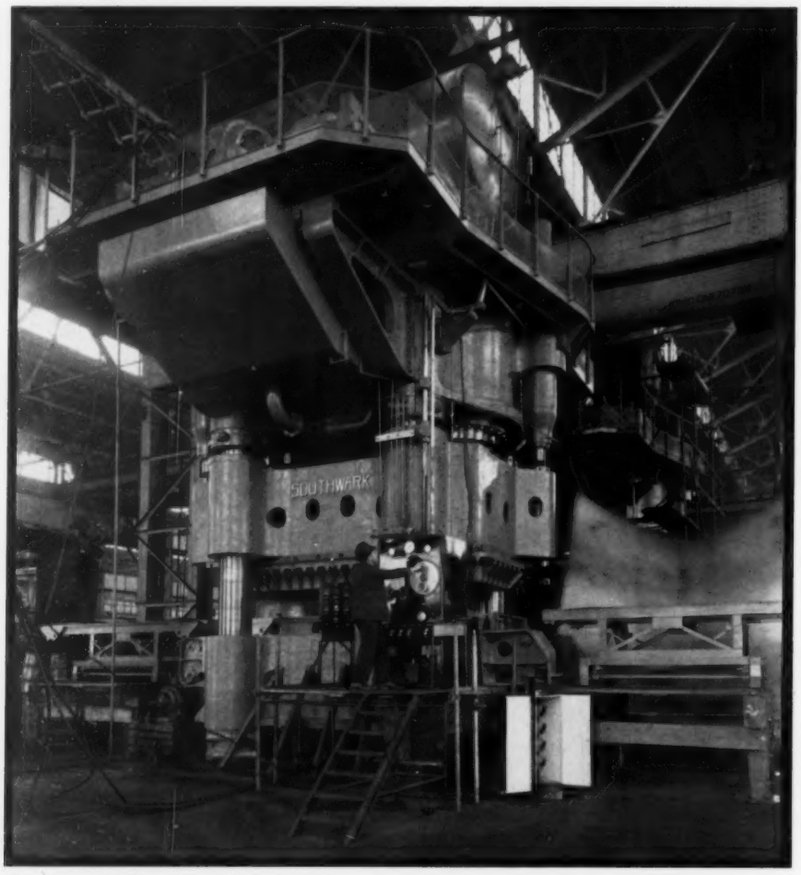
TELESCOPIC DUMP TRAILER

Speed intraplant hauling . . . reduce manpower hours. Tilting racks dump long bars, shapes and pipes,—quickly, easily! Built ruggedly for hard usage and long service. Traveling cranes not required.

MANUFACTURERS SINCE 1863 — PHILLIPS MINE AND MILL SUPPLY COMPANY — PITTSBURGH, PENNA.

MINE & INDUSTRIAL CARS—FABRICATED STEEL—IRON CASTINGS

LARGE HYDRAULIC PRESS FOR FORMING DURALUMINUM AIRCRAFT PARTS



This massive 5,500-ton capacity Southwark hydraulic press is one of three just completed by the Baldwin Southwark Division of the Baldwin Locomotive Works especially for forming duralumin aircraft parts. The press is of the rapid-action type, and is completely automatic, having control of pressure, operating speed, and length of stroke. It also is equipped for semi-automatic or manual operation.

Press platens are single steel castings and weigh approximately 160,000 pounds each. Electric motors, with a total of 400 hp, are required to operate the pumps located on the platform which is 30 feet long, 23 feet wide, and which supports the complete power unit, control gear and operating valves.

The press stands 33 feet high and weighs approximately 960,000 pounds.

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theme in text and by photographs and diagrams. The equipment described consists of Micromax temperature recorders for use with thermocouples or with thermohm resistance thermometer bulbs. Applications to temperature measurement of steam, feedwater and cooling water, and to fuel, combustion air and flue gas, are described in detail.

A welcome addition to this publication is a description of the company's optical pyrometer, as used for checking of fuel bed and other combustion chamber temperatures.

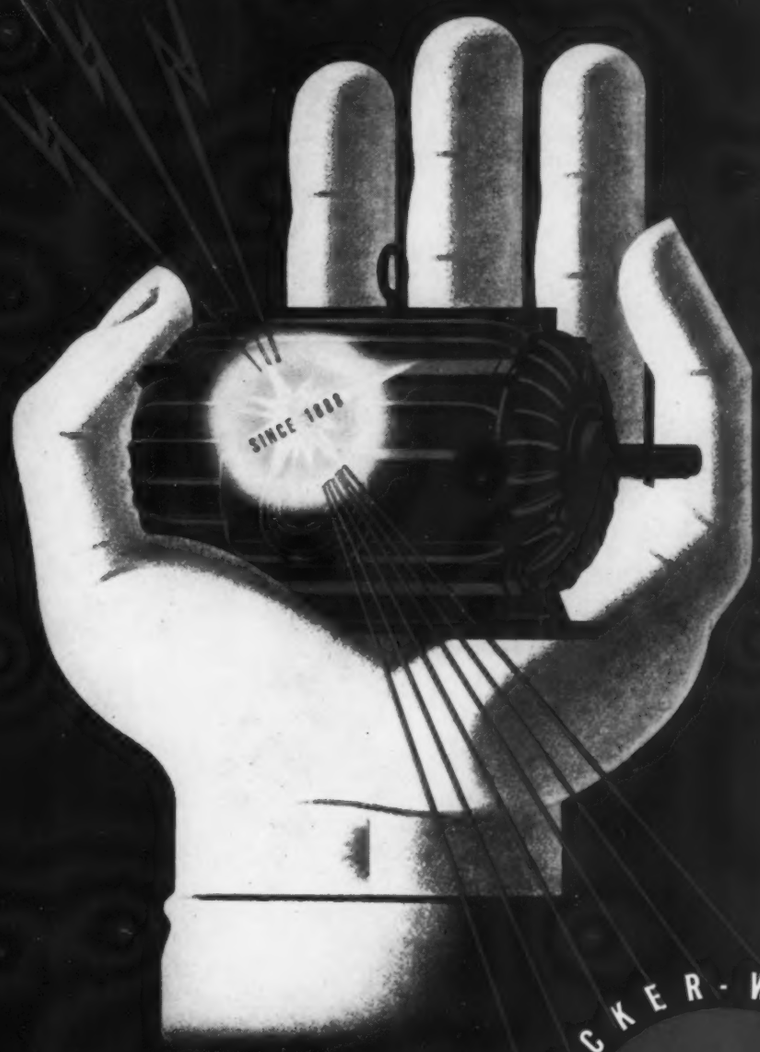
Although not a text book, this catalog contains a simple description of the principles of the thermocouple and potentiometer, the thermohm and the wheatstone bridge, which are the fundamental elements of the instruments described.

If you want a copy of this catalog ask Leeds and Northrup Company, 4934 Stenton Avenue, Philadelphia, Pennsylvania, for Catalog N-33-163, "Micromax Temperature Instruments for the Steam Plant."

MILWAUKEE PLANTS RECEIVE "E" AWARD

Five Milwaukee plants of Cutler-Hammer, Inc., were recently awarded the Army-Navy "E" for outstanding production of war materials. Rear Admiral Clark H. Woodward made the presentation, and the award was accepted for the company by Frank R. Bacon.

NEED MOTORS OR GENERATORS?



IF you need motors or generators, write or wire us . . . or consult your nearest Crocker-Wheeler office.

We can make *immediate* deliveries on some types . . . but regardless of type, we can deliver in faster time than ever before.

New and vastly increased productive facilities, plus expert Joshua Hendy planning are the reasons. Crocker-Wheeler Electric Mfg. Co., Ampere, N. J. Division of JOSHUA HENDY IRON WORKS

CROCKER-WHEELER

TRADE MARK REG. U. S. PAT. OFF.

Be SURE . . . with
CROCKER-WHEELER

Other JOSHUA HENDY IRON WORKS factories at Sunnyvale, Pomona and Torrance, California and St. Louis, Mo.

ITEMS OF INTEREST

C. E. Powell has been appointed manager of the machinery department of the R. D. Wood Company, Philadelphia, Pennsylvania.

Mr. Powell, who joined the R. D. Wood Company in 1936, is well-known in the hydraulic machinery field. In addition to numerous improvements and patents on machine and control designs, he has contributed many ideas during the present war crisis to high speed press and control design for the hydraulic forging of non-ferrous and aircraft metals; also to valve control for the country's largest and fastest high speed ferrous metals hydraulic forging presses.

C. E. POWELL

Born in New Castle, Pennsylvania, he was graduated from Carnegie Institute of Technology in mechanical engineering, in 1919. Since then he has served as a hydraulic engineer with Pittsburgh Crucible Steel Company and sales engineer with Worthington Pump and Machinery Corporation.

In 1925 he entered the employ of Homestead Valve Manufacturing Company, becoming chief engineer and production manager.

Mr. Powell was also a full time instructor on the faculty of Carnegie Institute of Technology and was associated with Professor W. Trinks in his private consulting practice.

C. S. Kepler has resigned as sales manager of C. B. Hunt and Son, Salem, Ohio, manufacturers of pneumatic and hydraulic pressure specialties, and has taken over the state of Ohio for the sale of the company's products. He is located in Akron, Ohio.

William C. Fork, superintendent, hot strip rolling mills, Acme Steel Company, Chicago, has been named to the newly created position of general superintendent of the entire Riverdale plant. **Walter F. Hinkle,** assistant hot mill superintendent, will fill the position vacated by Mr. Fork, while **James F. Hanihan** will become assistant to Mr. Hinkle. Mr. Hinkle began his employment with Acme as an engineer in April, 1926, and in December of the following year, became assistant hot mill superintendent. Mr. Hanihan started with Acme in 1925 after a number of years in steel mills in the Pittsburgh area.

C. R. Coburn was recently appointed assistant superintendent of the finishing division of the seamless mills at the Campbell Plant, Youngstown Sheet and Tube Company.

Mr. Coburn became associated with the Youngstown Sheet and Tube Company on August 2, 1926, as turn foreman, electrical maintenance, on the new seamless tube mills which were being installed at that time. Previous to this date he had been employed at the Ohio Works located in Youngstown, of the U. S. Steel Corporation.

On July 7, 1931, he was made general foreman of the electric maintenance on the seamless mills; January 1, 1935, general foreman of the electric maintenance on the newly installed 79 inch continuous hot mill; December 12, 1937, general foreman of electrical and mechanical maintenance of the seamless mills.

In 1942 Coburn was made general foreman of maintenance of the entire tube division at the Campbell Plant which includes seamless, butt-weld and lap-weld mills. He occupied this position until his appointment as general foreman of the electric weld mill, electric weld finishing division and plate mills at the Brier Hill plant on February 15, 1943.

T. A. Cleary has been appointed superintendent of the open hearth department, of the Brier Hill Plant, Youngstown Sheet and Tube Company.

Mr. Cleary's first connection with this organization was in 1915 in the open hearth department. In 1937 he had advanced to junior melter and in 1939 to melter. On July 16, 1940 he was made assistant superintendent, which position he held up to the time he was appointed to his present position.

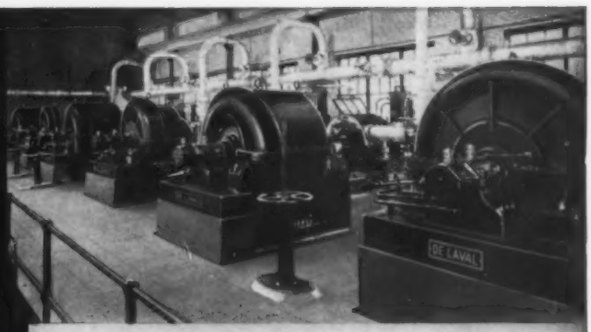
H. E. Engelbaugh has been appointed assistant general superintendent, Campbell Works, Youngstown Sheet and Tube Company.

Mr. Engelbaugh became associated with the company on August 24, 1925 in the labor department, from which he transferred to the inspection division. In 1927 he was made foreman of inspectors; in 1931, assistant chief inspector; in May 1937, superintendent of the seamless tube mills and in June 1941, superintendent of tube mills for the Youngstown district. He served in this capacity until his present appointment.

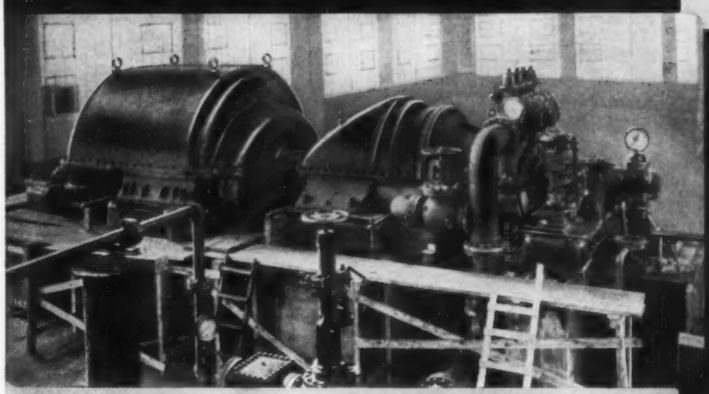
B. J. Hogan has been appointed assistant supervisor of industrial relations, Youngstown Sheet and Tube Company. He first started in the steel industry on February 1, 1907 as yard clerk with Brier Hill Steel. In 1923, when this company was purchased by the Youngstown Sheet and Tube Company, he was transferred to the safety and police department.

In 1924 he was appointed captain of police at the Brier Hill Plant and later in that year chief of police of the Eastern District. In 1937 he was appointed assistant superintendent of property protection, which position he held until his present appointment.

For Air and Gas Blowers, Compressors and Exhausters *Consult* DE LAVAL



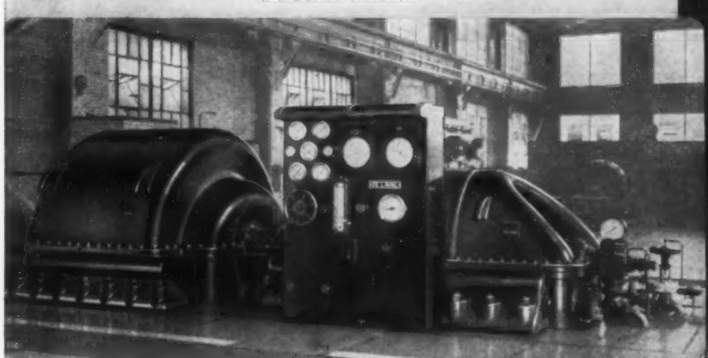
Six De Laval turbine-driven exhausters and boosters in a coke-oven plant. Three are rated at 31,365 c.f.m. each, two at 18,600 c.f.m. each, and one at 25,200 c.f.m.



A 115,000 c.f.m. turbine-driven compressor on test at the De Laval Works.

During recent years numerous repeat orders for De Laval air and gas handling equipment have been entered by large blast furnace plants, by-product coke-oven operators, and domestic gas works. In constructing both the steam power and gas ends of these machines, and also the controls, advantage has been taken of the latest improvements in design and in materials, and their satisfactory operation is testified to by the fact that the users come back to De Laval again as needs expand.

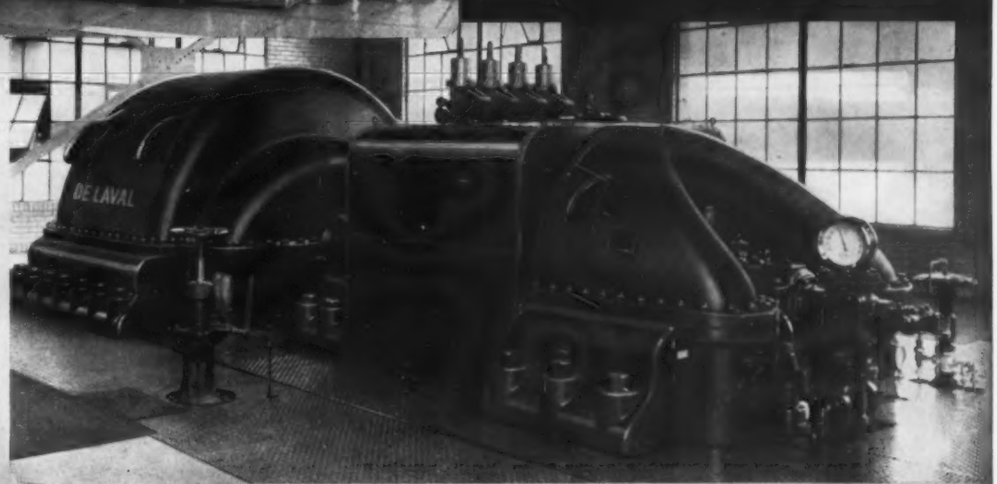
Ask for Catalog F-3824, which contains tables, charts and instructions for the solution of gas handling problems.



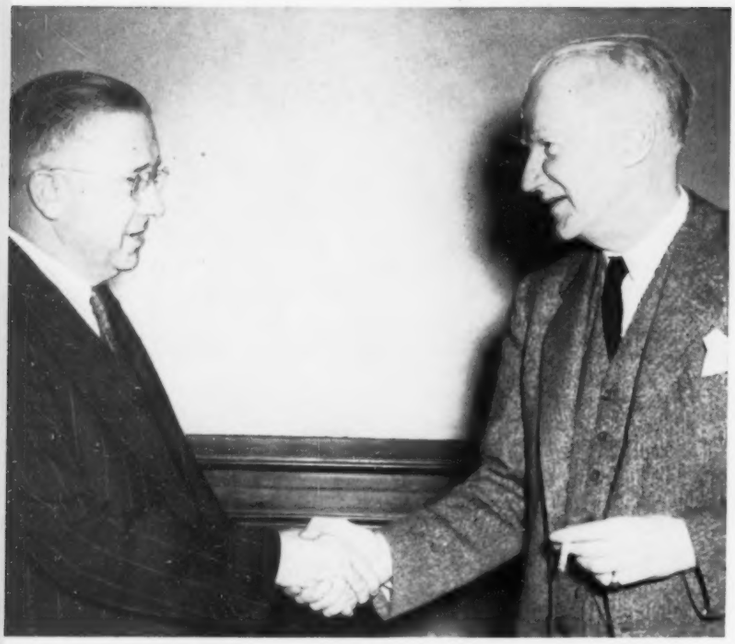
75,000 c.f.m. unit installed earlier in same plant and for same conditions as 85,000 c.f.m. blowers shown below.

• • •

Turbine-driven blast furnace blower; 85,000 c.f.m. of air against 30 lb. at 2800 r.p.m.; turbine using steam at 400 psig and 700° F.



DE LAVAL STEAM TURBINE CO. . . TRENTON, N. J.



Two pioneers in the field of continuous strip rolling meet as John B. Tytus (right), of American Rolling Mill Company, greets F. E. Flynn, of Republic Steel Corporation.

J. B. Tytus has been elected vice president in charge of technical development for The American Rolling Mill Company. Mr. Tytus has been vice president in charge of operations at Armco, and is internationally known as the developer of the continuous method of rolling iron and steel sheets.

Mr. Tytus, who was graduated from Yale in 1897, started to work in the Armco sheet mills in 1904 as a doubler. He became superintendent of the Zanesville Armco plant in 1906, and superintendent of the Middletown sheet mill department in 1909. He was appointed assistant general superintendent in 1918. During the World War I period, Mr. Tytus conducted a series of experiments on the continuous rolling of iron and steel sheets. In 1922, he was sent to the newly-acquired Armco plant in Ashland, Kentucky, and there built the first successful continuous sheet rolling mill. The process Mr. Tytus developed is now used by all major steel companies in the United States and several in foreign countries. He was elected vice president in 1927.

F. E. Vigor has been elected vice president in charge of manufacturing and mining operation of The American Rolling Mill Company.

Mr. Vigor joined the Armco organization in 1910 as a traffic clerk, and was general manager of traffic when he was appointed assistant general manager of the Ashland Division in 1928. He was appointed manager at Ashland in 1929. In 1941 Mr. Vigor went to Washington as a member of the iron and steel section of the office of production management, eventually becoming

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To help you determine the possible extent of the market for your products in this strong, active field, we'll gladly give you market information based upon the uses for your products and our knowledge of the industry. Give us your sizes, types, uses, etc. and we'll give you all the help we can.

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assistant director of the steel division of the war production board. He recently returned to again take up his responsibilities on the staff of Armco general management.

Frank D. Egan has been granted an indefinite leave of absence due to illness from his position as electrical superintendent of the Bethlehem Steel Company, Lackawanna, New York. Mr. Egan had been superintendent of this department since 1923. He attended Grove City College, Ohio University and the University of Pittsburgh. Previous to being with the Bethlehem Company,

FRANK D. EGAN

Mr. Egan had been associated with the National Tube Company, Crucible Steel Company of America and the Westinghouse Electric and Manufacturing Company. Mr. Egan is a past president of the Association of Iron and Steel Engineers, and for many years has served as chairman of its standardization committee.

Robert W. Graham succeeds Frank D. Egan as superintendent of the electrical department. Mr. Graham graduated from Cornell University. After serving there for three years as an instructor he came to Lackawanna in 1916, as assistant superintendent of the electrical department. During the first World War he

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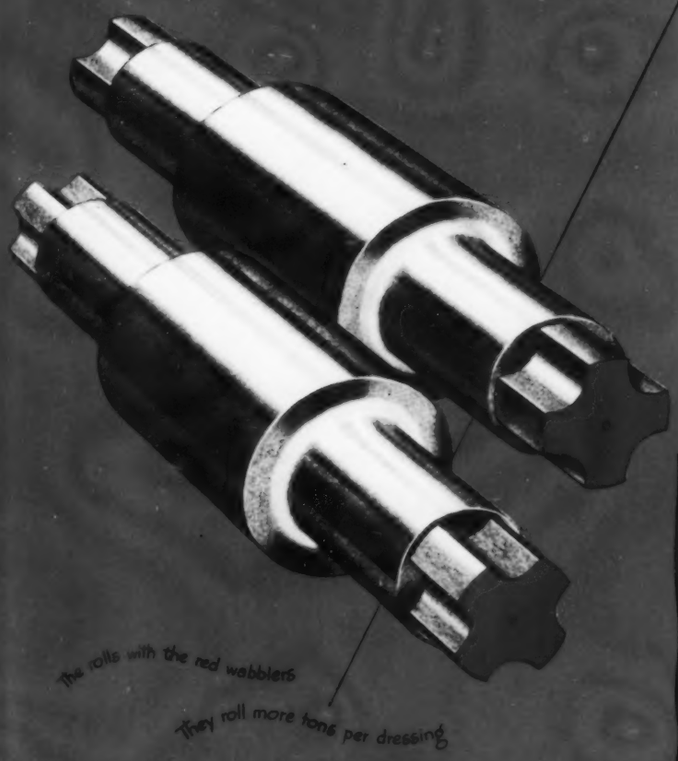
Hytensite Rolls have the strength of steel...

The wearing and finishing properties of cast iron



The M-H Hytensite Rolls are high test alloy cast iron, specially treated. They contain appreciable proportions of visible graphite finely and uniformly distributed throughout, with a corresponding uniformity of structure of wearing and finishing qualities. They have a tensile strength of 60,000 to 100,000 lbs. per sq. in., with hardness of 50 to 70 Scl. (C scale). They are cast iron, and as such are free from the deleterious "notch effect" of steel. Small radii in the neck fillets and various passes, do not adversely weaken the roll.

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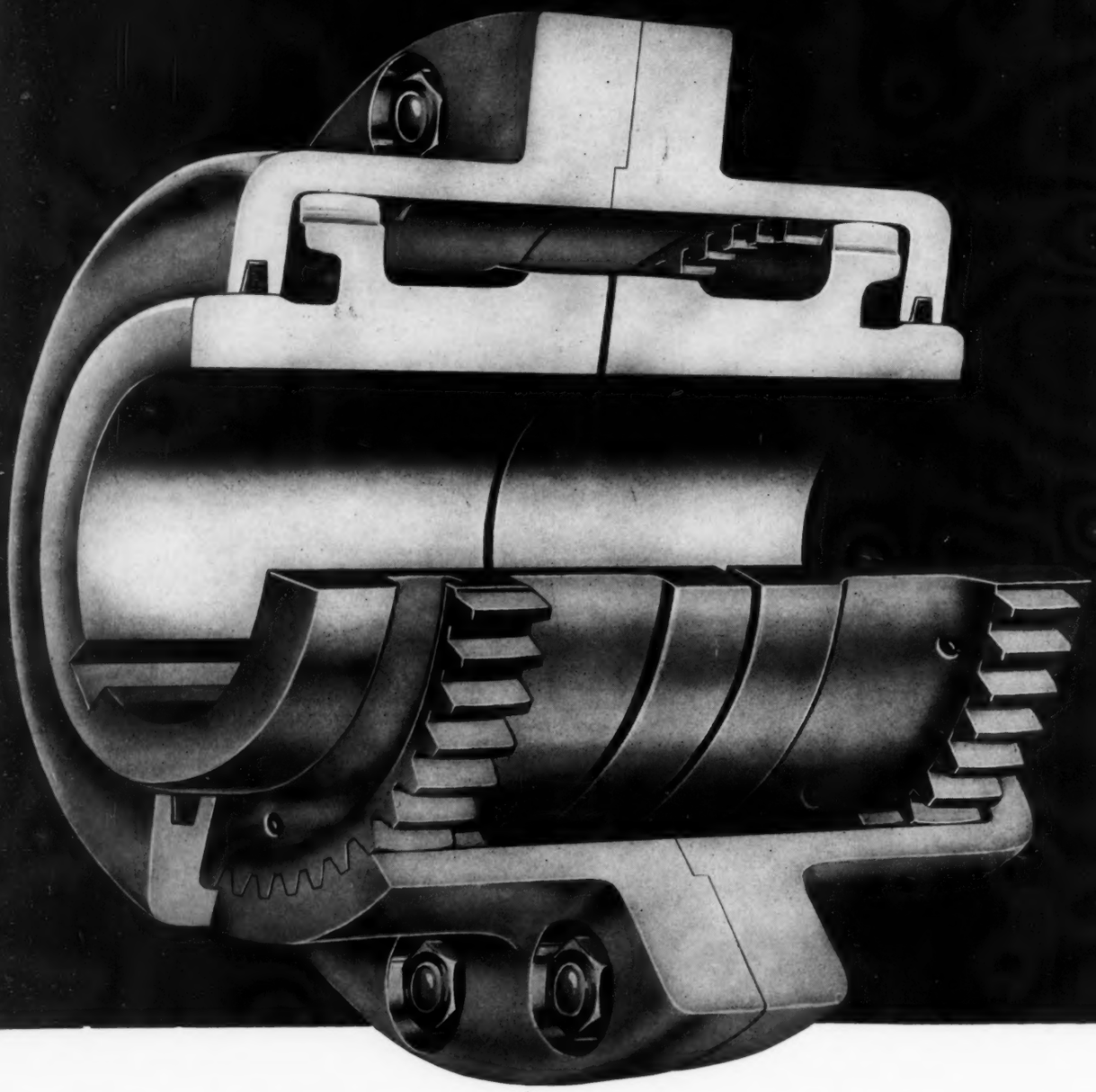
POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

spent a year and a half in the U. S. Navy. **Theodore O. Zittel** takes Mr. Graham's place as assistant electrical superintendent.

Robert W. Pugh has been appointed superintendent of the coke oven department at the Lackawanna plant of Bethlehem Steel Company. Mr. Pugh has been with Bethlehem Steel Company since his graduation from Clemson A. & M. College in 1924. After a brief stay at the Fore River Shipyard, Quincy, Massachusetts, he was transferred to the Lackawanna Plant, where he was assigned to the coke oven department. In 1931 he became assistant superintendent of the department.

Benjamin W. Winship whom Mr. Pugh succeeds, has held the position of superintendent of the Lackawanna coke oven department since 1929. He is a graduate of Drake University and has spent almost his entire career with Bethlehem, having formerly served at Sparrows Point and Steelton.

John W. Haddock has been elected president of Farrel-Birmingham Company, Inc. Mr. Haddock was formerly vice president of the Sullivan Machinery Company of Claremont, New Hampshire and Michigan City, Indiana.

Mr. Haddock started his industrial career as a stock clerk in the Michigan City plant of the Sullivan Machinery Company. Here he also worked as a ship apprentice, clerk and assistant production manager. Later he was transferred to the Claremont plant. From there he went to the company's New York City office as salesman, then to the general offices in Chicago as assistant to the general sales manager, and later became assistant vice president in charge of sales.

In 1935 he was made general manager of the Michigan City division with complete charge of the plant and the engineering, manufacture and sale of its products. Since 1938 he has been vice president in charge of engineering and sales for the company, dividing his time between the Claremont and Michigan City plants.

Axel S. Hellstrom is now a member of the staff of the Parsons Engineering Corporation of Cleveland, Ohio. He was formerly associated with the Broden Construction Company, subsidiary of the Wean Engineering Corporation.

Edwin A. Jones having resigned as blast furnace superintendent for the Jackson Iron and Steel Company has accepted a similar position with the Globe Iron Company, Jackson, Ohio. Over a period of thirty years he had been associated with Pittsburgh Steel, Cambria

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Steel, Adrian Furnace, Trumbull Cliffs Furnace, Sloss Sheffield Steel, Pittsburgh Coke and Iron and Wheeling Steel Corporation.

W. H. Yeckley was recently appointed assistant superintendent of the Brier Hill Plant, Youngstown Sheet and Tube Company. He first came to this company as a test engineer in the fuel division on May 17, 1937 from the Lorain Plant of the National Tube Company.

Mr. Yeckley served in this capacity until January 1, 1938 when he was appointed assistant superintendent of the open hearth department of the Brier Hill Plant. On July 15, 1940 he was promoted to superintendent of the same division and served in this capacity until his appointment to his present duties.

Louis F. Sattele has been appointed assistant general superintendent of the Lorain, Ohio, Works, the National Tube Company announced recently.

The appointment of Mr. Sattele re-establishes the policy of having two assistant general superintendents at this U. S. Steel subsidiary plant. Earl C. Tatum, now assistant general superintendent, will remain in his present position.

Mr. Sattele, whose entire business career has been with the National Tube Company, has served in various capacities for 21 years. He goes to Lorain from the position of assistant general superintendent, Ellwood City Works.

M. S. Gettig has been appointed superintendent of the seamless mills, Youngstown Sheet and Tube Company. He first entered the employ of the Youngstown Sheet and Tube Company on May 16, 1937. He came to Youngstown from American Well and Prospecting Company in whose employ he served as foundry superintendent.

The most effective defense against leakage on all vital flow-lines in steel plants

—for controlling gas, oil, residues, air and water

Sizes: ½" to 30".

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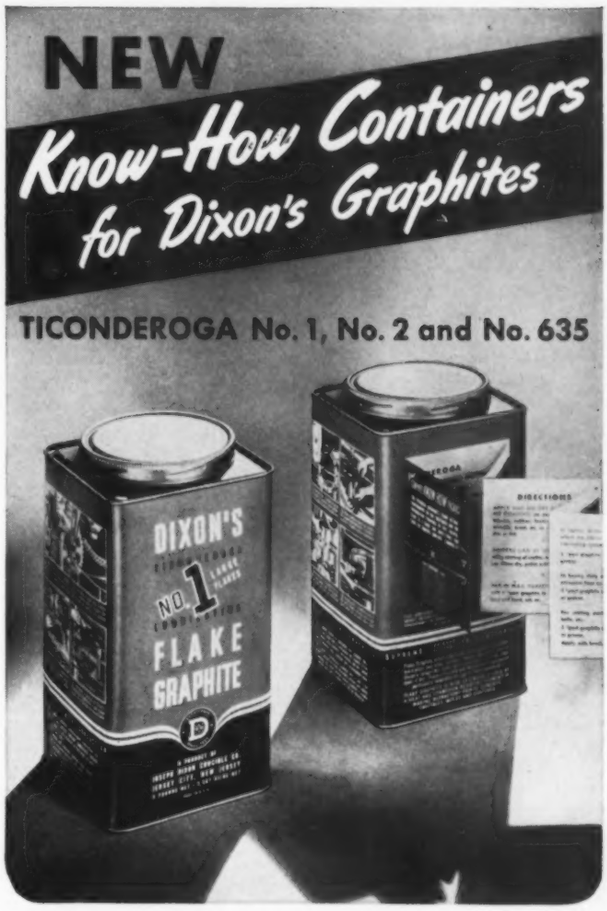
Mr. Gettig attended Penn State College where he graduated in 1928 with a B. S. degree in metallurgy. During his high school and college years he was employed part time in the chemical laboratories of the National Tube Company. After graduating from Penn State he was employed in the research laboratory for National Tube until 1930, when he was transferred to the Lorain, Ohio, plant of the same company as a metallurgist. He remained in this position until 1935 when he entered the employ of American Well and Prospecting Company.

T. A. Mullaly has been appointed superintendent of the butt and lap-weld pipe division of the Campbell Plant of the Youngstown Sheet and Tube Company.

Mr. Mullaly became associated with Youngstown 35 years ago on May 1, 1908, when he entered the employ of this company as a tally clerk in the tube mills. He later on became chief clerk and in January 1916 chief shipper for the tube division. January 1922 Mr. Mullaly was appointed general foreman of the tube mills and in January 1934 assistant superintendent of the butt-weld and lap-weld pipe mills, which position he held until his present promotion.

J. B. Brunot, Jr., has been appointed assistant superintendent of butt and lap-weld mills at the Campbell Plant of the Youngstown Sheet and Tube Company. He first came to the company in October 1938 as assistant superintendent of the fuel division. He formerly was connected with the Pennsylvania Industrial Engineers of Pittsburgh, Pennsylvania.

On May 1, 1940 Mr. Brunot was appointed assistant superintendent of the butt-weld mills, and on April 1, 1943 to his present position.



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PURDY PIX

Over 800 Attend A. I. S. E. Rolling Mill Meeting

An attendance of 825 at the first meeting of the A. I. S. E. Rolling Mill Committee, held in Pittsburgh, May 10th, is ample justification of the decision to establish this committee. Because of prevailing conditions, the meeting was limited to a single day, with technical sessions in the afternoon and evening. Between these sessions, a dinner was held, at which Hiland G. Batcheller, head of the Iron and Steel Division, War Production Board (1), spoke on the steel expansion program.

Mr. Batcheller said that the blast furnace program is less than half completed and will not be finished before the end of November. Coke oven construction will be completed in December. Open hearth expansion, he stated, is only 20 per cent finished and will continue until February, 1944 — six months behind schedule. Electric furnace capacity will reach its goal in November, 3½ months late.

Dealing only with blooming and slabbing mills, the program included papers by R. H. Wright, Joseph Sparks and H. H. Talbot (2) at the afternoon session. This session was under the co-chairmanship of Freeman H. Dyke and J. D. Jones, shown with Frank E. Flynn, Association president (3).

The evening session was headed by Louis Moses who is shown (4) with H. G. R. Bennett, general chairman of the Rolling Mill Committee, and C. L. McGranahan, Association vice-president. Papers were presented at this session by J. B. Holbrook and O. A. Bamberger (5). In (6), A. H. Burchfield, Jr., C. L. McGranahan, J. A. Clauss, J. L. Miller and Freeman H. Dyke register interest in J. S. Murray's dissertation on why a blooming mill bears no flowers.

The reactions and comments of the fine crowd attending the meeting indicates a fine future for the activities of the Rolling Mill Committee, which will broaden its future programs to include other types of mills.

1

2

3

4

5

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7

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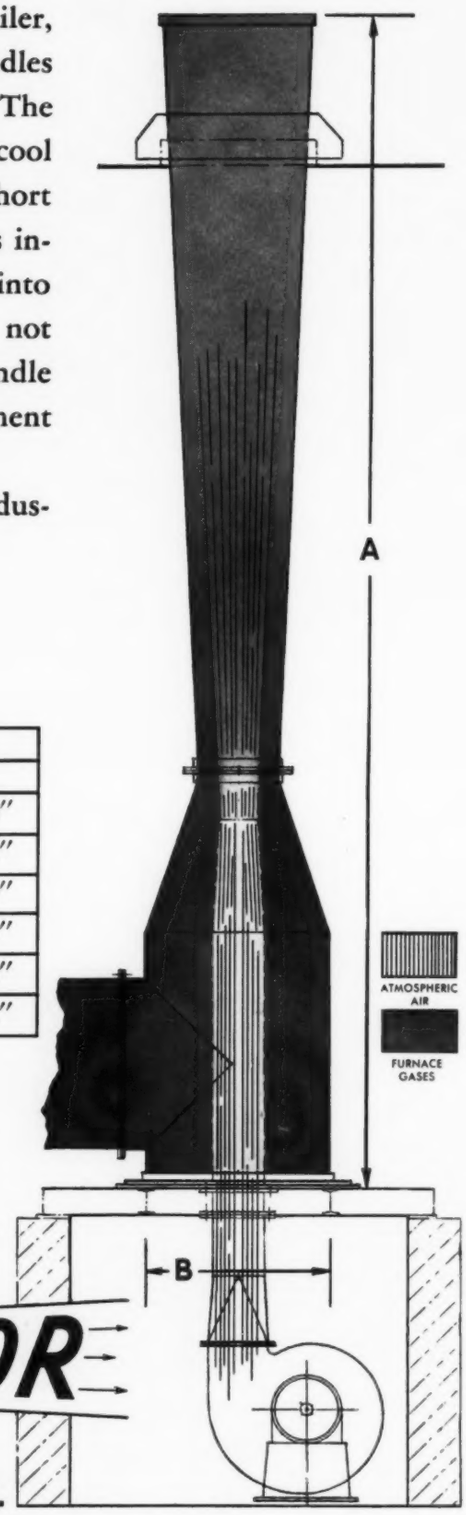

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(Draft at Airjector Base "@" W.G. 1)

SIZE	GALLONS OIL PER HR.	TEMP. OF EXHAUST GAS	FAN MOTOR H.P.	DIMENSIONS A	DIMENSIONS B
No. 1	50	1000°F	7½	20′-6″	3′-8″
2	75	1000°F	10	23′-8″	4′-2″
3	100	1000°F	15	27′-9″	4′-9″
4	130	1000°F	20	31′-6″	5′-3″
5	175	1000°F	20	34′-11″	5′-8″
6	225	1000°F	25	38′-6″	6′-2″

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Induction Motors (slip ring)				+	
Crane and Hoist Motors	+		+		
Synchronous Motors					+
Industrial Motors				+	
Mill Type D.C. Motors			+		
Industrial Generators	+		+		
Rotary Converters		+	+	+	
Single Phase Commutator Motors		+	+		
Polyphase Commutator Motors		+	+		
Characteristic of Brush Grades	E24	E31	E35	688	2685
Polishing Action	0	0	0	3	2
Carrying Capacity (amps.)	60	70	75	150	65
Contact Drop	VH	VH	VH	VL	L

VH—Very High VL—Very Low L—Low

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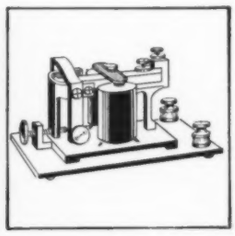
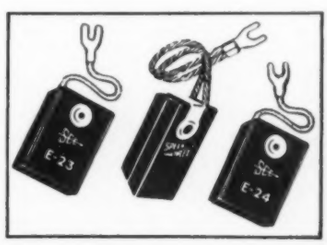


Magnetic Telegraph, 1832



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Sure, there is—but how long is it since *you've* done anything about it? These plans won't run without winding, any more than your watch! Check up on it today. If it doesn't show substantially more than 10% of your plant's pay-roll going into War Bonds, it needs winding!

And you're the man to wind it! Organize a vigorous drive. In just 6 days, a large airplane manufacturer increased his plant's showing from 35% of employees and 2½% of pay-roll, to 98% of employees and 12% of pay-roll. A large West Coast shipyard keeps participation jacked up to 14% of pay-roll! You can do as well, or better.

By so doing, you help your nation, you help your workers, and you also help yourself. In plant after plant, the successful working out of a Pay-Roll Savings Plan has given labor and management a common interest and a common goal. Company spirit soars. Minor misunderstandings and disputes head downward, and production swings up.

War Bonds will help us win the war, and help close the inflationary gap. And they won't stop working when victory comes! On the contrary—they will furnish a reservoir of purchasing power to help American business re-establish itself in the markets of peace. *Remember, the bond charts of today are the sales curves of tomorrow!*

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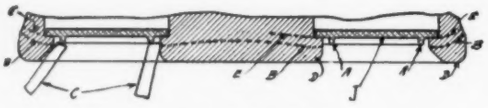

Note wear line B B B

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MODERN STEEL MILL LUBRICANT

Better Lubrication at Less Cost per Month

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Rockbestos A.V.C. Power Cable above and similarly insulated Motor Lead Cable (Underwriters' and Nat. Elec. Code, Type AVA) has a maximum operating temperature rating of 110° C. (230° F.) and this permanently insulated construction.

1. A tough, rugged asbestos braid, resistant to heat, flame, moisture, oil, grease and corrosive fumes.
2. Outer felted asbestos wall which serves as a heat-barrier against high ambient temperatures.
3. Lubricated varnished cambric for high dielectric strength and added moisture resistance, protected from heat and flame by two felted asbestos walls.
4. Felted asbestos insulation that withstands conductor-heating overloads and won't burn even when exposed to copper-melting arcs.
5. The conductor is perfectly and permanently centered in helically applied insulation.

One of 122 different wires and cables developed for severe operating conditions.

WON'T bake brittle, bloom, burn or rot — RESISTS moisture, oil, grease and fumes

One of the surest and simplest ways to eliminate wire failures in circuits that run around boilers, soaking pits, furnaces, lehrs, kilns, and other high temperature locations is to wire with *permanently insulated* Rockbestos A.V.C.

Built to withstand severe operating conditions, Rockbestos A.V.C. won't crack, bake brittle, bloom, rot or swell. It resists heat, flame, moisture, oil, grease and corrosive fumes.

Protect your production against interruptions caused by wire failures with Rockbestos A.V.C. wire, cable and cord. 122 *permanently insulated* constructions are available to fit practically every service requirement. Special constructions can be manufactured to meet special applications.

When inquiring or ordering, please give end-use classification and authorized preference rating. For full information, write nearest branch office, or:

Rockbestos Products Corporation, 893 Nicoll St., New Haven, Conn.

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The Wire with Permanent Insulation

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A BREAK IN THE ELECTRICAL CIRCUIT

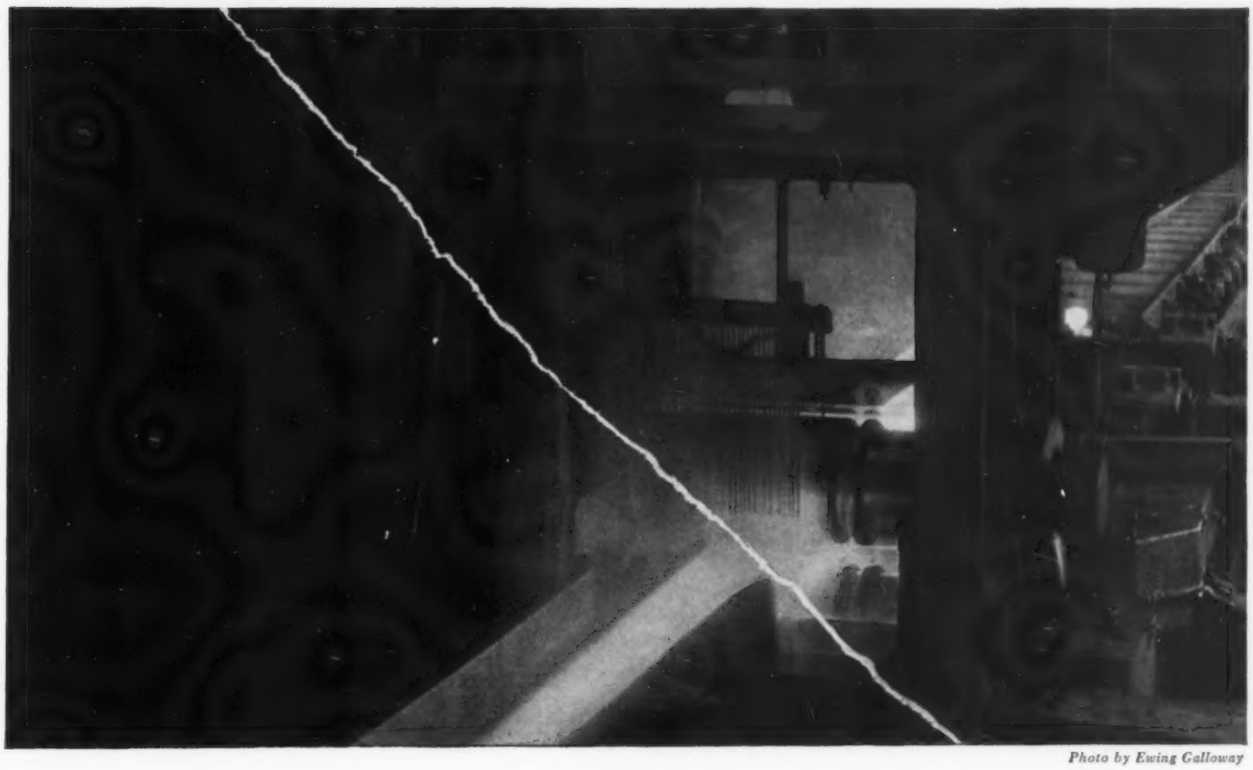


Photo by Ewing Galloway

MEANS A BREAK IN STEEL PRODUCTION!

Conditions under which electrical circuits must operate in steel mills, such as proximity to steam lines, boilers, furnaces, soaking pits, pouring ladles, drying ovens, pickling baths and in other places where resistance to heat, moisture, corrosive fumes, oils, grease and even fire, require the selection of insulated cables that will stand up under such severe service conditions. Okolite-Okoprene cables,* for instance, have successfully demonstrated their reliability in steel mill operation.

There are other Okonite cables that may solve your problems. Okonite sales engineers are experts in the selection, installation and maintenance of electrical cables. They are also able to give the answers to such questions as: (1) What cables are now available; (2) Priorities; (3) Government restrictions and limitations; (4) Deliveries. They can tell you how to prolong the life of existing cable installations. Bring your electrical cable problems to Okonite . . . The Okonite Company, Passaic, N. J. Offices in Principal Cities.

*OKOLITE-OKOPRENE—insulated with Okolite and protected with an Okoprene sheath. Resists moisture, heat, ozone, sunlight, oil, chemicals and flame. No lead sheath required. No braids to rot. High current carrying capacity and breakdown voltage. Low specific inductive capacity and power factor. Available in colors for circuit identification and in all standard sizes for use up to 5,000 volts.

3288

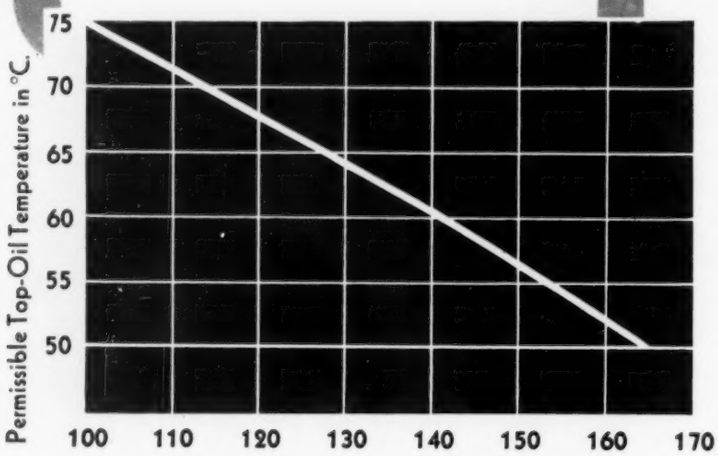
OKONITE

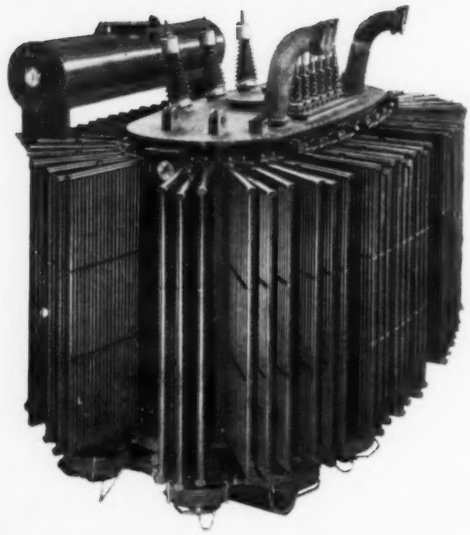
OKONITE Insulated Wires and Cables

SIMPLIFIED REFERENCE TABLE TO HELP ANY OPERATOR

OVERLOAD

PENNSYLVANIA POWER TRANSFORMERS





20,000 kva, 25-cycles, OISC, outdoor, three phase, rated 4400-6600 volts, with forced air cooling equipment to permit increased capacity of 26667 kva without exceeding temperature rise of 55°C.

HOW TO USE OVERLOAD TEMPERATURE CURVE

With any continuous load shown on the curve, the corresponding top oil temperature must not be exceeded.

EXAMPLE: If a transformer, while carrying 100% load, is found to have a top oil temperature of 75°C., and it is desired to carry 30% overload on this transformer, additional cooling must be provided to bring the top oil temperature down to 64°C. when the transformer is carrying 130% load.

It is not always necessary to provide additional cooling in order to obtain additional capacity. Low ambient temperature, low load factor, and similar conditions will permit the transformer to be overloaded to the extent shown on the curve, as long as the corresponding permissible oil temperatures are not exceeded.

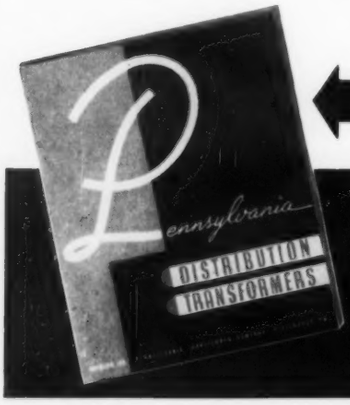
ADDITION OF FORCED COOLING

Increased rating may be obtained economically by the addition of forced-air-cooling, fans, or forced-oil-cooling units. For information as to type, number, and size of fans and cooling units, you are invited to consult our Engineering Department.

LIMITATIONS

The above guide applies to Pennsylvania Power Transformers which have been properly operated and maintained. The oil must be in good condition as indicated by dielectric strength and color. Samples of oil may be sent to our factory where they will be tested without charge.

Before applying overloads to transformers, a careful check should be made of the thermal capability of all associated equipment, such as circuit breakers, switches, current transformers, cables, meters and relays. Before exceeding 135% load on any transformer, it is recommended that advice be obtained from our Engineering Department as to any limitations involved, such as oil expansion, pressure in sealed-type units, bushing ratings, etc.



Standard transformers available in sizes up to 150 Kva.
Write for our new catalog on Distribution Transformers.

Pennsylvania
TRANSFORMER COMPANY
PITTSBURGH, PENNSYLVANIA

Pennsylvania TRANSFORMERS

INDEX TO ADVERTISERS

A

Aetna-Standard Engineering Company 1
Air Reduction Sales Company 24
American Hammered Piston Ring Division of Koppers Company 89
American Hoist and Derrick Company 112
Askania Regulator Company 100

B

Bantam Bearings Corporation 87
Bartlett-Hayward Division of Koppers Company 89
Bonnot Company 23
Broden Construction Company 8
Brown Instrument Company 29

C

Clark Controller Company 27
Cleveland Crane and Engineering Company 6
Clipper Manufacturing Company 106
Crocker-Wheeler Electric Manufacturing Company 97
Crouse-Hinds Company 90
Cutler-Hammer, Inc. ..... Cover 2

D

De Laval Steam Turbine Company 76-99
Joseph Dixon Crucible Company 107

E

Electric Controller and Manufacturing Company 15
Electric Storage Battery Company 11
Engineering and Construction Division of Koppers Company 89

F

Flinn and Dreffein Company 8

G

Gas and Coke Division of Koppers Company 89
Gatke Corporation 82
General Electric Company ..... Cover 4-17-18-19-20

H

Hallden Machine Company 8
Hays Corporation 91
Heppenstall Company 85
Hyatt Bearings Division General Motors Corporation 83
Hydropress, Inc. 3

I

Ingersoll-Rand Company 46
I-T-E Circuit Breaker Company ..... Cover 3

K

C. M. Kemp Manufacturing Company 94
Koppers Coal Company 89
Koppers Company 89
Koppers Rheolaveur Company 89

L

Leeds and Northrup Company 25
Lewis Foundry and Machine Division, Blaw-Knox Company ..... Cover 1-9
Loftus Engineering Corporation 102

M

Mackintosh-Hemphill Company 103
Maryland Drydock Company 89
Mathews Conveyer Company 30
James H. Matthews and Company 102
McKay Machine Company 8
Merco Nordstrom Valve Company 106
Mesta Machine Company 10
Morgan Construction Company 110
Morgan Engineering Company 14
Morganite Brush Company 112

N

National Bearing Metals Corporation 105
National Carbon Company, Inc., Carbon Sales Division 84
National Roll and Foundry Company 76
New York and New Jersey Lubricant Company 114
Norma-Hoffmann Bearings Corporation 120
North American Manufacturing Company 93

O

Ohio Electric Manufacturing Company 114
Okonite Company 117

P

Pennsylvania Transformer Company 118
Philco Corporation Storage Battery Division 2
Phillips Mine and Mill Supply Company 95
Pittsburgh Lectromelt Furnace Corporation 32
Poole Foundry and Machine Company 104
Post-Glover Electric Company 21

R

Reliance Electric and Engineering Company 16
Rockbestos Products Corporation 115
Rowan Controller Company 105-107

S

SKF Industries, Inc. 28
Socony-Vacuum Oil Company, Inc. 13
Speer Carbon Company 111

T

Tar and Chemical Division of Koppers Company 89
Timken Roller Bearing Company 22
Truflo Fan Company 86
Tube Turns, Inc. 102

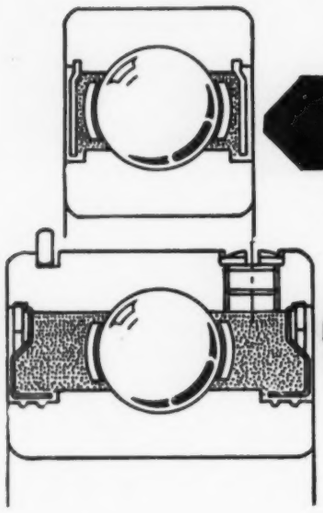
U

Union Carbide and Carbon Corporation 84
United Engineering and Foundry Company 4-5

W

Wagner Electric Corporation 26
Wapakoneta Machine Company 105
Wean Engineering Company, Inc. 8
Wean Engineering Company of Canada, Ltd. 8
Wellman Smith Owens Engineering Corporation, Ltd. 8
Western Gas Division of Koppers Company 89
Westinghouse Electric and Manufacturing Company 12
White Tar Company of New Jersey, Inc. 89
Wood Preserving Corporation 89

YOU CAN'T GET A QUART INTO A PINT MEASURE



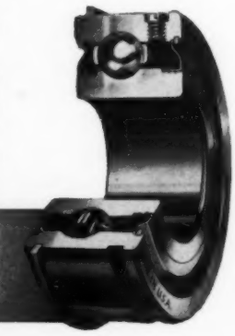
And, "by the same token," you can't get as much grease into a single-row-width "sealed" ball bearing, as goes into the double-row-width "CARTRIDGE" BALL BEARING of equal bore and outside diameter. Look at the section drawings herewith, and you'll see why.

In the single-row-width shielded or "sealed" bearing, see that very small grease space inside the sealing plates. Note further that there is no space available for a highly-efficient, truly grease-tight seal.

Now, in contrast, see that big grease reservoir between the seals, in the "CARTRIDGE" BEARING section—providing at least DOUBLE THE GREASE CAPACITY of the shielded or "sealed" bearing, and greatly extending the [illegible]g intervals. Note, too, how the wide, inwardly-extending seal flanges, and the oil grooves on the inner ring, provide AN IDEAL SEAL THAT PREVENTS THE ESCAPE OF GREASE AND EXCLUDES DIRT, whatever the shaft angle.

Furthermore, the "CARTRIDGE" SEALS ARE REMOVABLE AND REPLACEABLE, should you wish to inspect the bearing or change the grease. And the refilling plug makes it easy to put in a new charge of grease. You can't do this, with the ordinary shielded or "sealed" bearing, which is permanently sealed.

QUALITY, too, is just as vital as QUANTITY, in the grease in your bearings. So, every "CARTRIDGE" BEARING leaves our factory, packed with NORMA-HOFFMANN "STABILITY-TESTED" GREASE, which has great resistance to oxidation as well as excellent lubricating properties.



Summing up . . . all these distinctive features of the NORMA-HOFFMANN "CARTRIDGE" BALL BEARING mean prolonged bearing life, less lubrication attention and lower maintenance cost. Write for the Catalog, enumerating many additional advantages. Let our engineers work with you.

NORMA-HOFFMANN

"CARTRIDGE"

BALL BEARING

NORMA-HOFFMANN BEARINGS CORP'N, STAMFORD, CONN. • FOUNDED 1911

TO WIN THE WAR: *Work—Fight—Buy War Savings Bonds!*

SAVE MATERIALS AND MACHINES

On d-c motor drives...

FAULT CURRENTS CAN BE KEPT LOW

This ultra-high-speed circuit breaker is so fast that fault currents can't rise to dangerous values.

ON PRESENT DAY d-c systems with generators, converters or rectifiers connected in parallel, fault currents rise so rapidly that serious damage may be done before a conventional circuit breaker can limit the current. Ordinarily the circuit breaker will open in 3 cycles, in special cases in 1½ cycles, but with fault currents rising at a rate of several million amperes per second, such opening times permit flash-overs to burn brushes and brush-holders. Damage is done; production is stopped for repairs or replacements.

ULTRA-FAST OPENING IS THE ANSWER

The way to protect a system against the effects of rapidly rising currents is to hold the peaks to safe values. I-T-E does this with fast-opening circuit breakers. The Type FB circuit breaker, illustrated, has opening characteristics which limit currents within 2/5ths of a cycle (60 cycle basis).

IMPORTANT SAVING OF MATERIALS

When high fault currents are to be encountered, bus structures must be built with heavy conductors and heavy bracing. On the other hand, when peak currents are kept low by ultra-fast circuit breakers, much metal is saved; buses are much simpler.

HIGH-SPEED CIRCUIT BREAKERS HAVE PROVED THEIR VALUE

I-T-E has high-speed circuit breakers in service. They are new but their record is well-founded. Our engineers will gladly tell you about them.

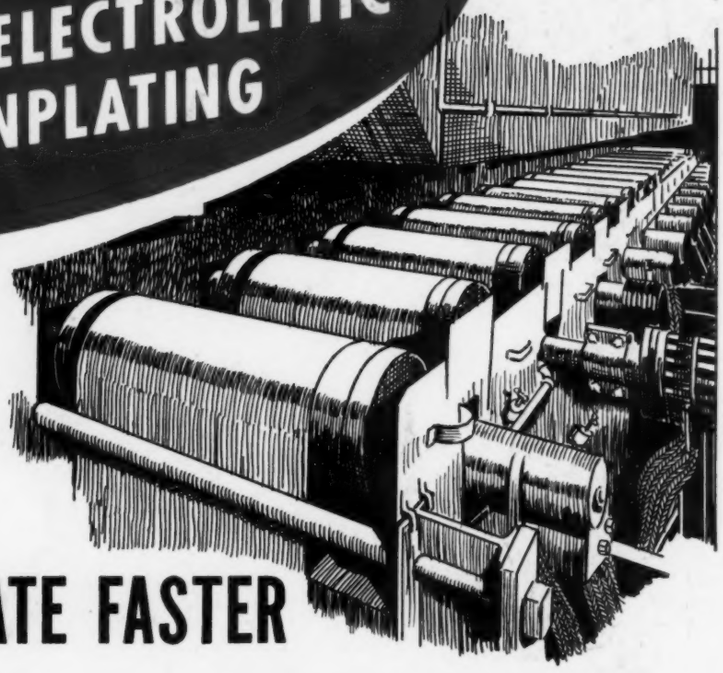
I-T-E **AIR SWITCHGEAR**

IMMERSED IN AIR • ENCASED IN STEEL

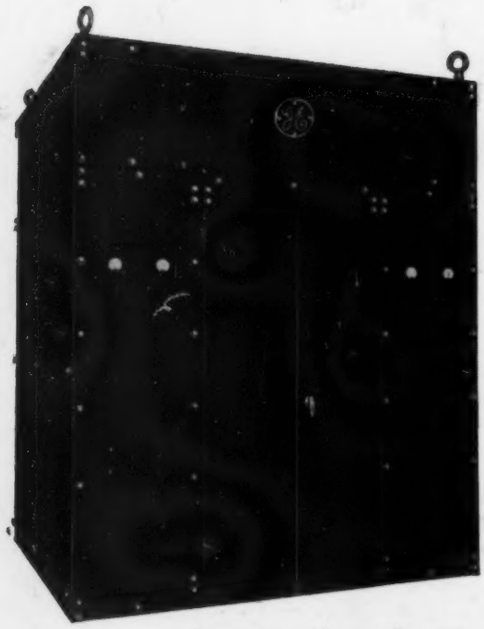
Representatives in Principal Cities

CIRCUIT BREAKER CO., PHILADELPHIA, PA.

60,000 AMPERES FOR CONTINUOUS ELECTROLYTIC TINPLATING



YOU CAN TINPLATE FASTER AND SAVE ⅔ THE PRECIOUS TIN



A copper-oxide rectifier unit for electrolytic tinning—5000 amp, 9 volts d-c. Approximately 9 ft high, 7 ft wide, and 6 ft deep.

THE electrolytic method of plating, for which General Electric has installed the electric equipment in several mills, produces tinplate at the rate of 500 feet per minute, and uses only ⅓ as much tin as the hot-dip method. This high-speed, low-cost method, which is economically justifiable under normal circumstances is becoming a ***must*** under war conditions.

The G-E dry-type rectifiers used on electroplating lines are easy to install, and they provide long life because there is nothing to wear out. No special foundations, or auxiliary venting or cooling equipment is required and, where floor space is at a premium, the rectifiers can be placed on balconies or platforms above the floor. Their control is extremely accurate, since saturable-reactor load control gives operation comparable to generator-field control.

If you would like more information about electric equipment for the new electroplating lines, see our representative at the G-E office nearest you. ***General Electric, Schenectady, N. Y.***

GENERAL ELECTRIC

660-27 14